Geophysical Investigations of the Waiilatpu Missions Grounds (45WW41) at Whitman Mission National Historic Site, Walla Walla County, Washington

Steven L. De Vore
Midwest Archaeological Center
National Park Service
Federal Building, Room 474
100 Centennial Mall North
Lincoln, Nebraska 68508-3873
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Introduction

The geophysical survey of the Waiilatpu Mission Grounds (45WW41) at the Whitman Mission National Historic Site in Walla Walla County, Washington, was conducted between June 22 and June 25, 2005, by Midwest Archeological Center archeologist Steven De Vore. Located in Section 32, Township 7 North, Range 35 East, of Walla Walla County, Washington (Figure 1), the geophysical investigations were conducted for the evaluation of the condition of the known archeological resources and to identify unknown archeological resources within the Waiilatpu Mission Grounds. The park staff was particularly interested in identifying whether the building foundation footings were actually present in the location indicated by the 1940s archeological excavations and how deep were they buried below the present ground surface. A secondary priority of the project was also to provide clues to the extent of the pioneer cemetery. The geophysical investigations include the area of the First House, the Mission House, the Blacksmith Shop, and the Emigrant House within the Waiilatpu Mission Grounds (Figure 2). The total area of investigations was 4,800 square meters (1.19 acres). The geophysical investigations of the project area included a magnetic gradient survey with a fluxgate gradiometer, a conductivity survey with a ground conductivity meter, and a ground penetrating radar survey with a ground penetrating radar cart system and 400 mHz antenna. Roger Trick, resource manager, from Whitman Mission National Historic Site assisted in the geophysical project along with Youth Corps volunteers Shay Hicks and Alan Saldana. Jason Lyon, archeologist and integrated resource manager, from Nez Perce National Historical Park also assisted in the project.

The Whitman Mission National Historic Site commemorates the role that Marcus and Narcissa Whitman played in the establishment of the Oregon Trail and establishment of the Waiilatpu mission with the local Cayuse Indians. In 1836, the Whitmans and Spaldings traveled to Oregon Country with a group of fur trappers. Narcissa Whitman and Eliza Spalding were the first white women to make the trek across the continent. The Waiilatpu Mission served as an important emigrant stop along the Oregon Trail. This was to fuel the growing tensions between the missionaries and the local Cayuse. When a measles outbreak in 1847 decimated nearly half of the local Cayuse Indians, they blamed the missionaries for the deaths. In the ensuing conflict, the Whitmans were killed and an additional 60 people were taken hostage. The buildings at Waiilatpu Mission were ransacked and burned down. The shock of the missionaries' deaths eventually resulted in Congress making Oregon a U.S. territory. General background on the Waiilatpu Mission was documented in the diaries of Narcissa Whitman and Eliza Spalding (Drury 1997) and Mary Walker and Myra Eells (Drury 1998).

Archeological investigations of the Waiilatpu Mission Grounds (45WW41) have been conducted by the National Park Service since the 1940s. Thomas Garth's historical and archaeological work in the area of Whitman Mission spanned a time period of approximately ten years. Arriving in 1941, leaving briefly during the war years (1942-1945), and returning in 1946, to stay until 1950, Garth was the archaeologist and custodian of Whitman Monument which entailed historical research and archaeological investigations, as well as site interpretation for many interested visitors. During this period, he conducted excavations at the First House, Mission House, Blacksmith Shop, and Emigrant House locations within the Waiilatpu Mission Grounds (Garth 1948,1949;1960). During the 1960s, National Park Service archeologist Paul Schumacher conducted archeological investigations at the blacksmith shop and a possible location for Clarissa Whitman's grave (Schumacher 1960,1961).

Survey area: The Whitman Mission National Historic Site is located on the Walla Walla Plateau section of the Columbia Plateau province of the Intermontane Plateaus division of the North American continent (Fenneman 1931:251-271). The rolling plateau contains young incised valleys along the streams including the Walla Walla River, a tributary of the Columbia River. The area also lies within the Palusian biotic province (Dice 1943:42-44). Native vegetation consists of grasses on the uplands with wooded stream bottoms and with forested north slopes and mountain top ridges. Native grasses include wheatgrass, fescue, needle-and-thread, Indian ryegrass, sand dropseed, giant wildrye, alkali cordgrass, and alkali bluegrass (Harrison et al. 1964:5-6). Cottonwoods are the dominate forest species along the streams. The climate is dry with a mixture of continental and marine characteristics including rather hot and dry summers and relative mild winters (Dice 1943:43; Phillips 1964:3-4). The park lies within the Yakima-Hermiston-Ahtanum soil association of *mixed soils on alluvial fans, stream bottoms, and small outwash plains; precipitation, 12 to 16 inches* (Harrison et al. 1964:9) and the Umapine-Stanfield soil association of *saline or alkaline soils; precipitation, 8 to 12 inches* (Harrison et al. 1964:9). The geophysical survey is located within the Hermiston silt loam with zero to three percent slopes soil mapping unit (HmA). This unit consists of deep, well drained, soils on the valley floor located above the high water line (Harrison et al. 1964:26). This moderately permeable soil formed in alluvium that consists of loess, which washed down from the uplands (Harrison et al. 1964:26). The soil is moderately to highly fertile. Surface runoff is very slow with a high available water capacity. The soil is mildly to strongly alkaline.

The present geophysical survey is located on the Waiilatpu Mission Grounds on the right bank of the Walla Walla River. The mission grounds occupy the grassy valley floor and timbered area north of the river oxbow and pasture area in the park (Figure 3). A paved interpretative trail passes through the mission grounds. Located within the mission grounds are the archeological remains of the Whitman's original house (First House site), the Mission House site, the Blacksmith Shop site, the Emigrant House site, the Gristmill site, and the millpond. An irrigation ditch and mission road passes on the north side of these archeological resources.

Surface features: The archeological remains of the Whitman's original house (First House site), the Mission House site, the Blacksmith Shop site, the Emigrant House site, and the Gristmill site are identified by interpretative signs around the paved interpretative trail. The approximate location of the foundations of the First House site, the Mission House site, the Blacksmith Shop site, and the Emigrant House site are identified by landscaping cement blocks placed above the foundations after the archeological excavations. The remaining fruit trees of the orchard lie to the west of the First House site. The millpond is located in the southeast corner of the mission grounds.

Subsurface features: Archeological excavations identified the foundations of the four major buildings at the mission (Garth 1948,1949,1960; Schumacher 1960,1961). The First House measured 30 feet (9.1 meters) by 36 feet (11.0 meters) with a 12 foot (3.7 meters) wide lean-to attached to the 36 foot long west side (Drury 1997:129). The fireplace was in the center of the west wall and a cellar extended under the entire house but was shallow under the lean-to. Garth's (1948) excavations identified 18 inch (45.7 cm) thick adobe walls in the excavated cellar. The second residence or Mission House was a "T" shaped building that measured 32 meters in length (Drury 1997:136-137: Garth 1948,1949). The top part of the "T" measured approximately 61 feet (18.6 m) by 19 feet (5.8 m), while the bottom part of the "T" measured approximately 80 feet (24.4 m) by 22 feet (6.7m). The Emigrant House was built in part from adobe bricks removed from the First House (Drury 1997:139-140). It measured 32 feet (9.8 m) by 40 feet (12.2 m). Archeological excavations (Garth 1948:130) indicated that the foundation of the house measured 35.5 feet (10.8 m) by 37 feet (11.3 m). The remaining adobe bricks from the First House were used to build the Blacksmith Shop (Drury 1997:140). Garth (1948:129) indicated the Blacksmith Shop roughly a half circle measuring 26 (7.9 m) feet by 32.5 feet (9.9 m).

Survey Methodology

The geophysical survey was conducted at the request of Whitman Mission National Historic Site and the Nez Perce National Historical Park staffs. In order to identify the buried archeological resources associated with the four Waiilatpu mission buildings, the Midwest Archeological Center (MWAC) archeologist applied magnetic gradient, conductivity, and ground penetrating radar survey techniques to investigate and identify the extent and location of possible archeological features associated with the four building locations at the Waiilatpu Mission Grounds (Figure 4). Initially, the geophysical grid was established using the east side of the landscaping blocks outlining the Mission House. The mapping datum was set at the southeast corner of the long extension of the landscaping blocks at N5042/E5035 with an arbitrary elevation of 200 meters. The north-south reference of baseline for the survey grid orientation was set along the eastern edge of the landscaping blocks with the north reference point located at the northeast corner of the same line of landscaping blocks. This baseline is approximately one degree west of magnetic north. The N5042/E5040 point was set five meters east of the mapping datum point. A wooden hub stake was placed at this point and the eastern side of the grid was established with the N5040/E5040 grid point set two meters south of the wooden hub stake. The 20 meter corners of the grid surrounding the Mission House (Figure 5) and the First House (Figure 6) site locations were established and mapped with the Nikon field station (Nikon 1993). The geophysical grid was identified as Block 1 and measured 40 meters east-west by 60 meters north-south (Figure 7). The southwest corner of the Block 1 grid was identified as N0/E0. Using the N60/E40 grid point, the east-west base line for the Blacksmith Shop and the Emigrant House site locations was set out with wooden hub stakes placed at every 20 meter grid point. The southwest corner of Block 2 containing the Blacksmith Shop (Figure 8) was located at N5060/E5060 and measured 40 meters east-west by 25 meters north-south (Figure 9). The southwest corner of Block 3 containing the Emigrant House (Figure 10) was located at N5060/E5120 and measured 40 meters east-west by 35 meters north-south (Figure 11). Wooden stakes were placed at the 20-meter grid unit corners and grid corners. The outlines of the landscaping blocks were mapped along with the grid unit wooden hub stakes with the Nikon field station. The topographic data was downloaded into a laptop computer and the survey project map was constructed in Surfer 8 (Figure 4).

Twenty-meter ropes were placed along the east-west base lines connecting the grid unit corners. These ropes formed the north and south boundaries of each grid unit during the data collection phase of the survey. Additional ropes were placed at one-meter intervals across the grid unit in a north-south orientation. These ropes served as guides during the data acquisition. The ropes were marked with different color tape at half-meter and meter increments designed to help guide the survey effort. Sketch maps of Blocks 1, 2, and 3 (Figures 7, 9, and 11, respectively) illustrated the locations of above ground features including the landscaping block outline of the four buildings, the sidewalks, interpretative signs, irrigation sprinkler heads and valve boxes, and trees. The data were acquired across the grid units beginning in the lower left hand corner of each grid unit.

Survey grids: Nine complete 20 meter by 20 meter grid units and 5 partial 20 meter by 20 meter grid units (4,800 m^2 or 1.19 acres) were surveyed during the geophysical project.

Geophysical Survey Techniques

Geophysical prospection techniques available for archeological investigations consist of a number of techniques that record the various physical properties of the earth, typically in the upper couple of meters; however, deeper prospection can be utilized if necessary (David 1995). Geophysical techniques are divided between passive techniques and active techniques. Passive techniques are primarily ones that measure inherently or naturally occurring local or planetary fields created by earth related processes (Heimmer and De Vore 1995:7,2000:55; Kvamme 2001:356). The primary passive method utilized in archeology is magnetic surveying. Other passive methods with limited archeological applications include self-potential methods, gravity survey techniques, and differential thermal analysis. Active techniques transmit an electrical, electromagnetic, or acoustic signal into the ground (Heimmer and De Vore 1995:9,2000:58-59; Kvamme 2001:355-356). The interaction of these signals with buried materials produces alternated return signals that are measured by the appropriate geophysical instruments. Changes in the transmitted signal of amplitude, frequency, wavelength, and time delay properties may also be observable. Active methods applicable to archeological investigations include electrical resistivity, electromagnetic conductivity (including ground conductivity and metal detectors), magnetic susceptibility, and ground penetrating radar. Active acoustic techniques, including seismic, sonar, and acoustic sounding, have very limited or specific archeological applications.

Magnetic Gradient Survey

Instrument: Geoscan Research FM36 fluxgate gradiometer (Geoscan Research 1987)

Specifications: 0.05 nT (nanotesla) resolution, 0.1 nT absolute accuracy.

Survey type: magnetic gradient

Operators: Steven De Vore

A magnetic gradient survey is a passive geophysical survey (see Bevan 1998:18-29; Clark 2000:64-98; David 1995:17-20; Gaffney and Gater 2003:36-42,61-72; Gaffney et al. 1991:3-5,2002:7-9; Heimmer and De Vore 1995:7-20,2000:55-58; Kvamme 2001:357-358,2003:441,2005:434-436; Lowrie 1997:229-306; Milsom 2003:51-70; Mussett and Khan 2000:139-180; Scollar et al. 1990:375-519; and Weymouth 1986:341-370 for more details of magnetic surveys). The Geoscan Research FM36 fluxgate gradiometer (Figure 12) is a vector magnetometer, which measures the strength of the magnetic field in a particular direction. The sensors must be accurately balanced and aligned along the direction of the field component to be measured. The reference point for balancing and aligning the gradiometer and for zeroing the conductivity meter was established in Block 1 at N20/E20 and was used throughout the survey efforts.

The two magnetic sensors in the fluxgate gradiometer are spaced 0.5 meters apart. The instrument is carried so the two sensors are vertical to one another with the bottom sensor approximately 30 cm above the ground. Each sensor reads the magnetic field strength at its height above the ground. The gradient or change of the magnetic field strength between the two sensors is recorded in the instrument’s memory. This gradient is not in absolute field values but rather voltage changes, which are calibrated in terms of the magnetic field. The fluxgate gradiometer does provide a continuous record of the magnetic field strength.

The magnetic gradient survey was designed to collect 8 samples per meter along one-meter traverses or 8 data values per square meter. The data were collected in a zig zag fashion or bidirectional mode with the surveyor alternating direction of travel for each traverse across the grid. A total of 3,200 data values were collected for each complete 20 by 20 meter grid unit surveyed during the project. The magnetic data were recorded in the memory of the gradiometer and downloaded to a laptop computer at the completion of the survey. The magnetic data were imported into Geoscan Research's GEOPLOT software (Geoscan Research 2001) for processing. Both shade relief and trace line plots were generated in the field before the instrument's memory was cleared. Upon completion of the survey, the data were processed in GEOPLOT. The grid data file was transformed into a composite file and a zero mean traverse was applied to remove any traverse discontinuities that may have occurred from operator handling or heading errors. An image map of the magnetic gradient data was generated for the survey grid area (Figure 13). Upon completion of the zero mean traverse function, the data were interpolated by expanding the number of data points in the traverse direction and by reducing the number of data points in the sampling direction to provide a smoother appearance in the data set and to enhance the operation of the low pass filter. This changed the original 8 x 1 data point matrix into a 4 x 4 data point matrix. The low pass filter was then applied over the entire data set to remove any high frequency, small scale spatial detail. This transformation may result in the improved visibility of larger, weak archeological features. The data were then exported as an ASCII dat file and placed in the SURFER 8 contouring and 3d surface mapping program (Golden Software 2002). Individual image plots were also generated for the magnetic gradient data from Block 1 (Figure 14), Block 2 (Figure 15), and Block 3 (Figure 16). The magnetic data from the geophysical survey after applying the zero mean traverse function ranged from -216.7 nT to 237.1 nT with a mean of -0.228 nT and a standard deviation of 32.941 nT.

Conductivity Survey

Instrument: Geonics EM38 electromagnetic conductivity meter (Geonics 1992) with an Omnidata DL-720 polycorder (Geonics 1998)

Specifications: apparent conductivity of the ground in millisiemens per meter (mS/m); measurement precision ±0.1% of full scale deflection; 100 and 1000 mS/m conductivity ranges (4 digit digital meter).

Survey type: conductivity in the quadrature phase operating mode

Operators: Steven De Vore

The conductivity survey is an active geophysical technique, which induces an electromagnetic field into the ground (see Bevan 1983,1998:29-43; Clark 2000:171; Clay 2001:32-33,2002; Davenport 2001:72-88; David 1995:20; Gafeney and Gater 2003:42-44; Gaffney et al. 1991:5,2002:10; Heimmer and De Vore 1995:35-41,2000:60-63;

Kvamme 2001:362-363,2003:441-442,2005:434-436; Lowrie 1997:222-228; Mussett and Khan 2000:210-219; Scollar et al. 1990:520-590; Weymouth 1986:317-318,326-327 for more details of conductivity surveys). This survey technique measures the apparent soil conductivity. The present survey is conducted with a Geonics EM38 ground conductivity meter (Geonics 1992). The instrument is lightweight and 1.45 meters in length (Figure 17). The self-contained dipole transmitter (primary field source) and self-contained dipole receiver (sensor) coils are located at opposite ends of the meter. The intercoil spacing is 1 meter.

An electromagnetic field is induced into the ground through the transmitting coil. The induced primary field causes an electric current flow in the earth similar to a resistivity survey. In fact, a conductivity survey is the inverse of a resistivity survey. High conductivity equates to low resistivity and vice versa. The materials in the earth create secondary eddy current loops, which are picked up by the instrument's receiving coil. The interaction of the generated eddy loops or electromagnetic field with the earthen materials is directly proportional to terrain conductivity within the influence area of the instrument. The receiving coil detects the response alteration (secondary electromagnetic field) in the primary electromagnetic field. This secondary field is out of phase with the primary field (quadrature or conductivity phase). The in-phase component of the secondary signal is used to measure the magnetic susceptibility of the subsurface soil matrix.

Changes result from electrical and magnetic properties of the soil matrix. Changes are caused by materials buried in the soil, differences in soil formation processes, or disturbances from natural or cultural modifications to the soil. EM instruments are also sensitive to surface and buried metals. Due to their high conductivity, metals show up as extreme values in the acquired data set. On occasion, these values may be expressed as negative values since the extremely high conductivity signal of the metals cause the secondary coil to become saturated.

In archeology, the instrument has been used to identify areas of compaction and excavation as well as buried metallic objects. It has the potential to identify cultural features that are affected by the water saturation in the soil (Clark 2000; Heimmer and De Vore 1995:35-41). Its application to archeology results from the ability of the instrument to detect lateral changes on a rapid data acquisition, high resolution basis, where observable contrasts exist. Lateral changes in anthropogenic features result from compaction, structural material changes, buried metallic objects, excavation, habitation sites, and other features affecting water saturation (Heimmer and De Vore 1995:37). The conductivity survey can sometimes detect the disturbed soil matrix within the grave shaft. It can also locate large metal objects. Metallic trash on the surface and other small objects buried in the upper portion of the soil can degrade the search of the graves or other buried features (Bevan 1991:1310).

The meter was connected to the DL720 Polycorder for digital data acquisition (Geonics 1998). The conductivity survey was designed to collect in the continuous or automatic mode with readings collected every 0.25 second resulting in 4 samples per meter. The data were collected in a parallel fashion or unidirectional mode with the surveyor conducting the data acquisition in the same the direction of travel for each traverse across the grid. The data and header files stored in the polycorder were downloaded into the laptop computer at the end of the survey. The survey of the grid unit began in the lower left hand or southwest corner of the grid. The EM38 was used in the quadrature or conductivity phase, the vertical dipole mode, and one orientation parallel to the direction of travel along the traverses. It provided an exploration depth of approximately 1.5 meters with its effective depth around 0.6 meters in the vertical dipole mode. The instrument was nulled and calibrated at before the start of the survey at the same point used to balance and align the fluxgate gradiometer. The conductivity data were collected along every one-meter traverse at a sampling density of four samples per square meter in the geophysical survey area. A total of 19,750 data measurements were collected during the survey.

The data were downloaded to a laptop computer at the end of the survey of the geophysical project. The data were processed using the DAT38W software (Geonics 2002). After the transfer of the data and header files to the laptop computer, the files were automatically converted from the raw EM38 format to DAT38 format with the extension name of G38 (Geonics 2002:12-14). The data were then displayed as data profile lines (Geonics 2002:14-15). The individual EM38 data file was then converted to XYZ coordinate file in the Surfer data format. To create the XYZ file, the orientation or direction of the survey line was selected in the DAT38W program along with the data type and format (Geonics 2002:20-23). The resulting XYZ data file was transfer to the SURFER 8 mapping software (Golden Software 2002). The conductivity data were reviewed and an image plot was generated in SURFER 8. To further process the conductivity data, it was transferred to GEOPLOT. The conductivity data were stripped of the X and Y coordinates and then the Z values (measurements) were imported into GEOPLOT for further processing (Geoscan Research 2001). The resulting grid was formatted to form a composite file in GEOPLOT. The interpolation routine was applied to the data set to arrange the data in an equally spaced 4 x 4 square matrix. A high pass filter was then applied over the composite data set. The high pass filter was used to remove low frequency, large scale spatial detail such as a slowing changing geological 'background' trend. The data were then exported as an ASCII *.dat file and placed in the SURFER 8 mapping program. The Northing and Easting coordinates were corrected to actual grid location values. Finally, the data were presented in an image plot (Figure 18) and a contour plot. The mean for the conductivity data from the project area was 25.870 mS/m with a standard deviation of 51.991 mS/m (Figure 7). The minimum value was -3246.3 mS/m and the maximum value was 120.3 mS/m. Individual image plots were also generated for Block 1, (Figure 19), Block 2 (Figure 20), and Block 3 (Figure 21).

Ground Penetrating Radar Survey

Instrument: Geophysical Survey Systems Inc. (GSSI) TerraSIRch SIR System-3000 ground penetrating radar cart system with a 400 mHz antenna (GSSI 2003).

Specifications: SIR 3000: System hardware contains a 512 mb compact flash memory card as its internal memory. Accepts industry standard compact flash memory card up to 2 gb. Processor is a 32-bit Intel StrongArm PISC 206 mHz processor with enhanced 8.4" TFT display, 800 x 600 resolution, and 64k colors. The processor also produces linescan and O-scope displays. The gpr system uses one channel. It also uses the GSSI Model 623 survey cart with survey wheel for mounting the antenna and control unit. The 400 mHz Model 5103 ground coupled antenna has a depth of view of approximately 4 m assuming a ground dielectric constant of 8 with a range of 50 ns, 512 samples per scan, 16 bit resolution; 5 gain points, 100 mHz vertical high pass filter, 800 mHz vertical low pass filter, 64 scans per second, and 100 kHz transmit rate.

Survey type: ground penetrating radar

Operator: Steven De Vore

The ground-penetrating radar (gpr) survey is an active geophysical technique (see Bevan 1998:43-57; Clark 2000:118-120; Conyers 2004; Conyers and Goodman 1997; David 1995:23-27; Gaffney and Gater 2003:74-76; Gaffney et al. 1991:5-6,2002:9-10; Goodman et al. 1995; Heimmer and De Vore 1995:42-47,2000:63-64; Kvamme 2001:363-365,2003:442-443,2005:436-438; Lowrie 1997:221-222; Milsom 2003:131-140; Mussett and Khan 2000:227-231; Scollar et al. 1990:575-584; and Weymouth 1986:370-383 for more details of ground penetrating radar surveys). The gpr unit operated an antenna at a nominal frequency of 400 megahertz (mHz). The antenna was mounted in a cart that recorded the location of the radar unit along the grid line (Figure 22). The gpr profiles were collected along one-meter traverses beginning in the southwest corner of the grid block. The data were collected in a zigzag or bidirectional fashion with the surveyor alternating the direction of travel for each traverse across the grid. A total of 41 radar profiles were collected across the project survey area.

Ground penetrating radar surveys generally represent a trade-off between depth of detection and detail. Lower frequency antennas permit detection of features at greater depths but they cannot resolve objects or strata that are as small as those detectable by higher frequency antennas. Actual maximum depth of detection also depends upon the electrical properties of the soil. If one has an open excavation, one can place a steel rod in the excavation wall at a known depth and use the observed radar reflection to calibrate the radar charts. When it is not possible to place a target at a known depth, one can use values from comparable soils. Reasonable estimates of the velocity of the radar signal in the site's soil can be achieved by this method (Conyers and Lucius 1996). Using one of the hyperbolas on a radargram profile (Goodman 2005:76), the velocity was calculated to be approximately 0.04 meters per nanosecond (ns). For a time slice between 5 and 15 ns with the center at 10 ns (two way travel time), the approximate depth to the center of the gpr slice would be 20 cm. With a time window of 70 ns, the gpr profile extended to a depth of 1.4 meters.

The survey cart contained a data-logger (SIR 3000) with a display that allowed the results to be viewed almost immediately after they were recorded. The SIR 3000 was set to collect gpr data with the 400 mHz antenna at an antenna transmit rate of 100 mHz and the distance mode selected for use of the survey wheel on the cart. The scan menu was set with 512 samples, 16 bit format, 70 ns range or window, a dielectric constant of 8 (the default value), a scan rate of 100, and 50 scans per meter. In the gain menu, the gain was set to manual with a default value of 3. The gpr system was moved around the grid prior to the start of the survey to adjust the gain. If a location caused the trace wave to go off the screen, the gain was set to auto and then back to manual. The position was set to the manual mode with the offset value at the factory default and the surface display option set to zero. The filters were left at the default settings. With the setup completed, the run/stop button at the bottom of the display screen was selected and the collect mode was initiated. The gpr unit was moved across the grid and at the end of the traverse, the next file button was selected and data acquisition was halted. The gpr unit was placed at the start of the next line before saving the profile. Once the profile data was saved, the gpr unit was ready to collect the next profile line. The gpr data were recorded on a 512 mb compact flash card and transferred to a lap-top computer at the end of the survey.

The gpr radargram profile line data are imported into GPR-SLICE (Goodman 2005) for processing. The first step in GPR-SLICE is to create a new survey project under the file menu. This step identifies the file name and folder locations. The next step is to create the information file. The number of profiles are entered, along with the file identifier name, .dzt for GSSI radargrams, the profile naming increment of 1, the first radargram name (generally this is 1), direction of profiling, x and y beginning and ending coordinates, units per marker (set to 1), the time window opening in nanoseconds (70 ns), samples per scan (512 s/scn), the number of scans per meter (these profiles were collected at 50 scans per meter), type of data (16 bit). Selecting the create info file button completes the information file for the project. The information file can be edited if necessary to correct profile lengths. The 16-bit GSSI radargrams are imported into the GPR-SLICE project folder for further processing. The 16-bit data are then converted to remove extraneous header information and to regain the data. During the conversion process, the signal is enhanced by applying gain to the radargrams. Once the conversion process is completed, the next step is to reverse the profile data. Since the radargrams were collected in the zigzag mode, every even line needs to be reversed. The reverse map button shows the radargrams that are going to be reversed. The next step is to insert navigation markers into the resample radargrams. The GSSI SIR 3000 and the artificial markers button are selected to apply markers based on the total number of scans in the radargram. The show markers button allows one to view an example of a radargram with the artificial markers in place. The next step is to create the time slices of the profile data (Conyers and Goodman 1997; Goodman et al. 1995). The program resamples the radargrams to a constant number of scans between the markers and collects the time slice information from the individual radargrams. The number of slices is set to 20 slices. The slice thickness is set to 30 to allow for adequate overlap between the slices. The offset value on the radargram where the first ground reflection occurs is viewed in the search 0 ns subroutine. This value is used to identify the first radargram sample at the ground surface. The end sample is 512. The offset value in entered in the samples to 0 ns box. The cut parameter is set to square amplitude with the cuts per mark set to 4. The slice/resample button is selected for processing the radargrams. The final step in the slice menu is to create the XYZ data file. The grid menu is entered next in the processing steps. The beginning and ending values for the x and y coordinate are entered. The help set button is selected to set the x search radius, y search radius and the blanking radius. The grid cell size is set to 0.1 and the search type is rectangular. The number of grids equal 20 for the number of slices, and the starting grid number is 1. The Kriging algorithm is utilized to estimate the interpolated data. The Varigram button is selected to set the Kriging range, nugget and sill parameters. The start gridding button is selected and the gridded dataset is created. In this menu, a low pass filter may be applied to the dataset to smooth noisy data in the time slices. At this point, one may view the time sliced radar data in the pixel map menu. Figures 23, 24, and 25 illustrate the time slices from Blocks 1, 2, and 3, respectively. In addition, the original processed grid slices and the low pass filtered grid slices can be exported in the Surfer grid format. The surfer grid file is transformed into an image plot in Surfer. Generally, one time slice is selected for further display and analysis. Time slice 7 was selected from the ground penetrating radar data from Block 1 (Figure 26), Block 2 (Figure 27), and Block 3 (Figure 28) for further analysis. The gain may be readjusted for any time slice. This is done in the transforms submenu. The interpolations value is set to 5 and the interpolate grids routine is selected. The new interpolated grids are all normalized. The next step is to create the 3D dataset in the grid menu. The number of grids is now equal to 95 ((20-1)*5). The 3D database is created under the create 3D file routine. The 3D data may be displayed as a series of z slices in the creation of a 3D cube with a jpeg output for animating the 3D cube.

Interpretations

Andrew David (1995:30) defines interpretation as a "holistic process and its outcome should represent the combined influence of several factors, being arrived at through consultation with others where necessary." Interpretation may be divided into two different types consisting of the geophysical interpretation of the data and the archaeological interpretation of the data. At a simplistic level, geophysical interpretation involves the identification of the factors causing changes in the geophysical data. Archeological interpretation takes the geophysical results and tries to apply cultural attributes or causes. In both cases, interpretation requires both experience with the operation of geophysical equipment, data processing, and archeological methodology; and knowledge of the geophysical techniques and properties, as well as known and expected archeology. Although there is variation between sites, several factors should be considered in the interpretation of the geophysical data. These may be divided between natural factors, such as geology, soil type, geomorphology, climate, surface conditions, topography, soil magnetic susceptibility, seasonality, and cultural factors including known and inferred archeology, landscape history, survey methodology, data treatment, modern interference, etc. (David 1995:30). It should also be pointed out that refinements in the geophysical interpretations are dependent on the feedback from subsequent archeological investigations. The use of multiple instrument surveys provides the archeologist with very different sources of data that may provide complementary information for comparison of the nature and cause (i.e., natural or cultural) of a geophysical anomaly (Clay 2001). Each instrument responds primarily to a single physical property: magnetometry to soil magnetism, electromagnetic induction to soil conductivity, resistivity to soil resistance, and ground penetrating radar to dielectric properties of the soil (Weymouth 1986:371).

The limited ground penetrating radar survey of the pioneer cemetery suggested the possible location of some of the graves (Figure 29). The gpr survey was expedient in the sense that it was an attempt to verify the potential for a successful gpr survey in the cemetery. Several linear transects were evenly spaced in the open area of the cemetery. The resulting gpr profile lines were processed in GPRSLICE and time slices were generated (Figure 30). At least one strong gpr amplitude anomaly was present along the E40 line. Based on the resulting data from the pioneer cemetery gpr reconnaissance, it is highly likely that an intensive gpr survey of the cemetery area will yield results useful in the identification of unmarked graves.

The magnetic gradient data from the Waiilatpu Mission Grounds contains numerous dipole and monopole magnetic anomalies. Most noticeable in the three grids in the linear anomalies associated with the reinforced concrete sidewalks. In Block 1, several dipole anomalies appear spread across Block 1 especially on the west side of the First House site (Figure 31). This may represent a sheet midden of materials discarded by the Whitmans when they lived in the house. It is also possible that these anomalies represent burned adobe fragments from the burning of the buildings following the massacre. Numerous anomalies are also located between the Mission House and the First House sites. Although the two house site locations contain less dense concentrations of magnetic anomalies, it is interesting to note the number of anomalies appearing within the excavated areas of the Mission House and the First House site location. One would have expected few if any magnetic anomalies within the excavated areas. It is probable that such anomalies represent adobe foundations or fired chimney remnants. They may also represent backfill materials. A set of three linear anomalies at the First House site location suggest that the house foundation sits approximately three meters west of the present set of landscaping blocks outlining the house. The magnetic gradient data from the Mission House suggest that the landscaping blocks appear closely associated with the location of the adobe foundation. Several magnetic gradient anomalies are located in the area surrounding the Blacksmith Shop (Figure 32). The majority of these appear in linear alignments that suggest the locations of trail segments or fences. A series of linear anomalies also suggest that the location of the Blacksmith Shop adobe foundation lays a couple of meters to the west of the present landscaping blocks outlining the Blacksmith Shop location. One relative rectangular series of linear magnetic anomalies surrounds the Blacksmith Shop . Some may indicate the position of the buried irrigation lines. The Emigrants House location identified by the landscaping blocks is surrounded by magnetic anomalies (Figure 33). There also appears to be a light scatter of magnetic anomalies to the east and north of the house location. This may be the location of a sheet midden comprised of discarded materials from the residents of the house or other activities. It is also possible that these materials are from the destruction of the building following the massacre. The landscaping blocks appear to be placed on top of the adobe foundations uncovered during the archeological investigations of the mission site. A couple of negative value linear anomalies may represent trail locations near the house.

Several point conductivity anomalies are present in the conductivity data from the geophysical survey of the mission grounds. The point conductivity anomalies are generally associated with metal artifacts. The conductivity anomalies also appear to be in a similar concentration as the magnetic anomalies in the Block 1geophysical survey grid (Figure 34). Comparing the conductivity anomalies with the magnetic gradient anomalies, one can make several observations. For the overlapping magnetic gradient and conductivity anomalies, it is probable that these anomalies represent ferrous or iron based artifacts. In the cases where there is no corresponding magnetic gradient anomaly, the conductivity point anomaly typically represents a metal object but is not a ferrous based metal (i.e., it does not contain iron nor is it magnetic in nature). In the cases where there is no corresponding conductivity anomaly to the magnetic gradient anomaly, it is generally assumed that the magnetic gradient anomaly represents a non-metal object that contains ferrous compounds (e.g., construction debris consisting of burned adobe bricks) or a disturbed area of soil (e.g., a pit, trench, or other type of soil disturbance). In addition to the buried anomalies, several above ground features, including the sidewalks, wayside exhibits and irrigation related features are represented by anomaly clusters. Several linear conductivity anomalies coincide with the buried irrigation lines. In Block 2, a few conductivity point anomalies suggest the location of buried metal artifacts (Figure 35). These anomalies appear to coincide with the magnetic anomalies suggesting that the anomalies are iron artifacts. A couple of linear conductivity anomalies may represent the location of wagon paths near the blacksmith shop or associated fence lines, while others may be associated with the buried irrigation lines. The sidewalk is clearly visible in the conductivity data from the blacksmith shop area. The project area at the Emigrant House also contains a few conductivity point anomalies (Figure 36). Some coincide with the magnetic anomalies suggesting that these anomalies represent iron artifacts. A few others appear to represent other nonferrous metallic artifacts. The linear anomalies in Block 3 may also indicate the location of wagon paths or trails near to the north side of the building or buried irrigation lines. The reinforced concrete sidewalk is clearly visible.

The ground penetrating radar data from Block 1 indicates the presence of a few high amplitude strength anomalies (Figure 37). The time slice 7 from 19.3 to 23.4 ns was selected as a representative gpr layer. Concentrations of high amplitude anomalies in the center of the survey area coincide with the magnetic and conductivity anomalies associated with the extensive sheet midden. In the northern portion of the survey grid the high amplitude anomalous area north of the sidewalk is a shallow marshy area. The area surrounding and inside the two building locations contain very low amplitude values, which may coincide with the buried adobe foundations. In the area surrounding the blacksmith shop in Block 2, the low amplitude ground penetrating radar anomalies on the east and west side of the building appear to also represent segments of the buried adobe foundation (Figure 38). In Block 3, the low amplitude gpr anomalies inside the Emigrant House outline coincide with the north and south exterior walls and with the interior partition walls suggesting the locations of the buried adobe foundations (Figure 39). Depths to the adobe foundation walls in the four buildings are estimated based on the hyperbola calculations. The velocity was estimated to be approximately 0.04 meters per nanosecond. In Block 1 and Block 3, the depth to the adobe foundations of the First

House, the Mission House, and Emigrant House were located at approximately 10 ns (two way travel time). This gives an approximate depth of 32 cm. At the Blacksmith Shop, the travel time was approximately 16 ns. The resulting depth calculation yields a depth of 20 cm. These depth estimates are relative and based on the estimated time travel of the radar signal and ability to match the velocity as determined by the hyperbola matching. Actual depths may vary significantly for these estimates.

Conclusions

During June 2005, Midwest Archeological Center staff conducted geophysical investigations of the Waiilatpu Mission Grounds (45WW41) at the Whitman Mission National Historic Site in Walla Walla County, Washington. The geophysical survey was conducted in response to the park's request to technical assistance in the identification of the location of the buried adobe foundations associated with the four Waiilatpu Mission buildings. The park staff wanted to know if the foundations were present where the 1940's archeological investigations indicated and how deep the foundations may lie below the present ground surface. The geophysical investigations included a magnetic gradient survey with a fluxgate gradiometer, a conductivity survey with a ground conductivity meter, and a ground penetrating radar survey with a ground penetrating radar cart system and 400 mHz antenna. A total of 4,800 square meters or 1.19 acres were surveyed with the geophysical instruments. The geophysical survey of the mission grounds resulted in the identification of numerous subsurface anomalies including portions of the adobe foundations associated with the four mission buildings. The First House foundations appear to lie west of the landscaping blocks. The east and west sides of the blacksmith shop also appear to be slightly west of the landscaping block identifying its location. The foundations at the Mission House and the Emigrant House appear to be very closely associated with the present position of the landscaping blocks. The interior walls are present in the Emigrant House, but are less noticeable in the Mission House. It is difficult to identify the interior walls in geophysical data from the First House and the Blacksmith Shop

This report has provided a cursory review and analysis of the geophysical data collected during the geophysical investigations of the Waiilatpu Mission Grounds project areas. This information will be used by the park staff to verify the location of the buried adobe foundations of the buildings and to realign the surface landscaping block where needed. This information may also be used by the Whitman Mission National Historic Site staff to guide further archeological inquiry into the nature of the site and help direct future National Park Service archeological excavations in the mission grounds project area. It is also recommended that a complete geophysical survey be conducted across the mission grounds, as well as at the pioneer cemetery to provide the park staff with baseline geophysical data on the condition and extent of buried archeological resources associated with the Waiilatpu Mission.

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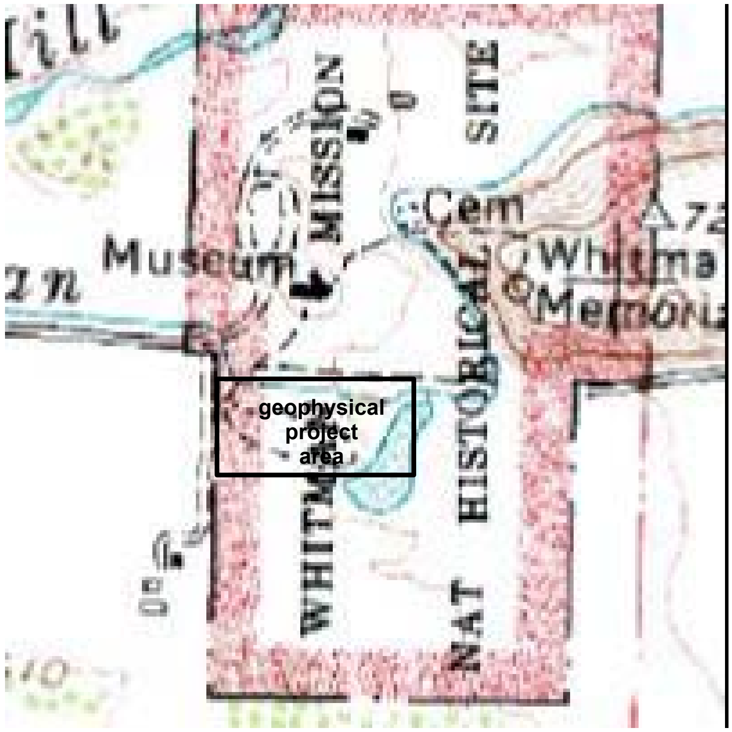
Figures



a) 11 kilometers west of Walla Walla, Washington (USGS topographic map dated 01 July 1978).

b) 11 kilometers west of Walla Walla, Washington (USGS aerial photograph, dated 01 July 1996).

Figure 1. Location of the project area at the Whitman Mission National Historic Site, Walla Walla County, Washington.

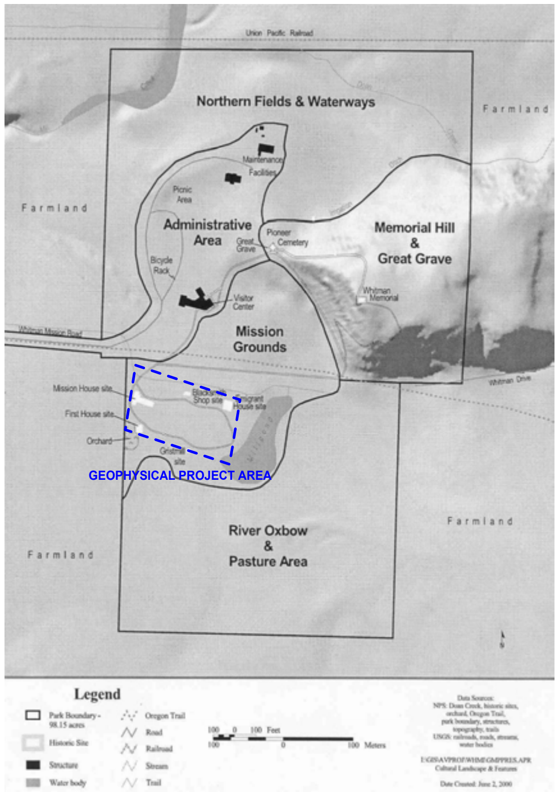


Figure 2. General geophysical project area within the boundary of the park.

Figure 3. General view of Mission Grounds geophysical project area (view to the southwest)

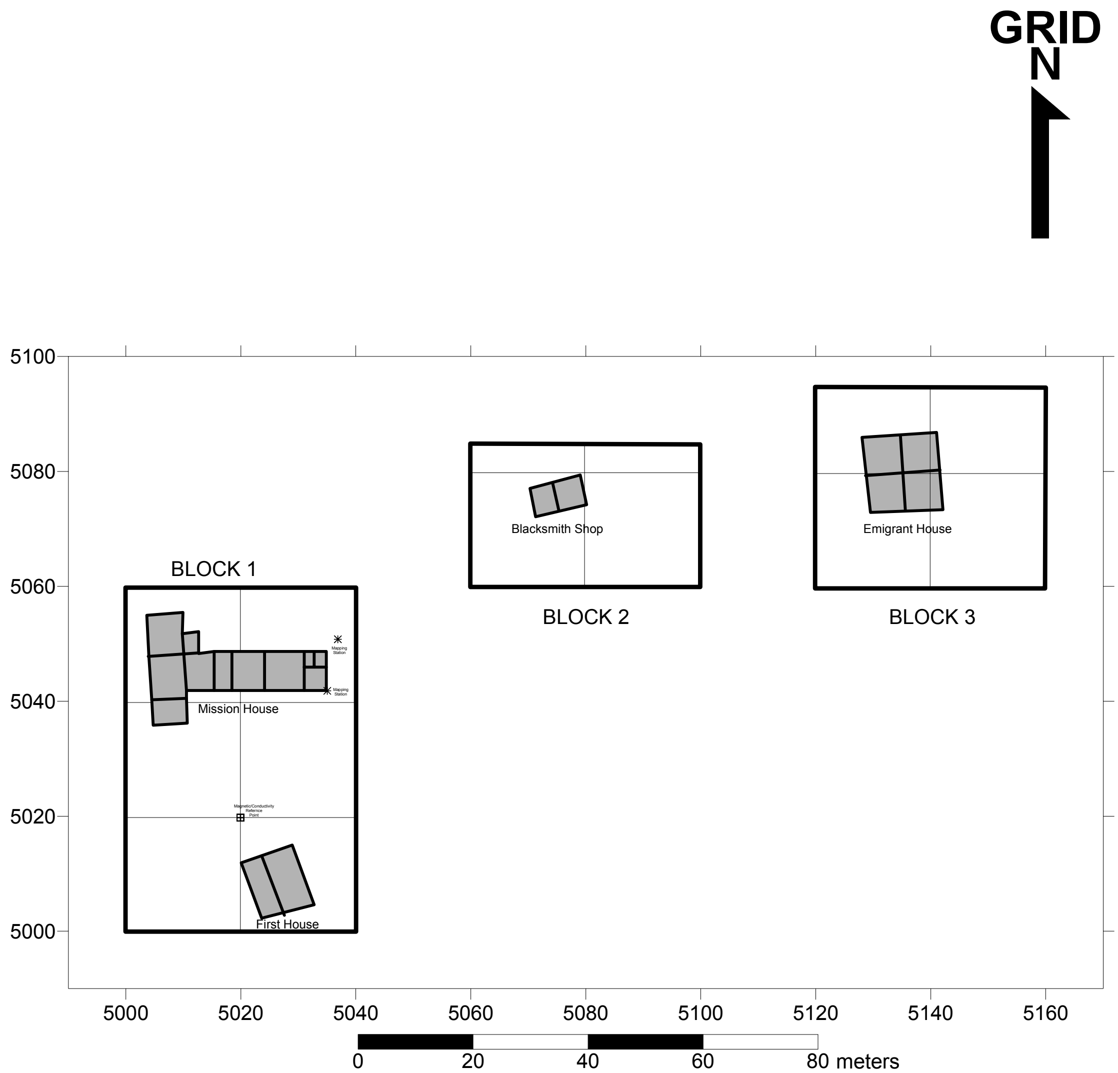


Figure 4. Location of building ruins and geophysical survey grids in the Mission Grounds project area.

Figure 5. General view of the Mission House area (view to the west northwest).

Figure 6. General view of the First House area (view to the southwest).

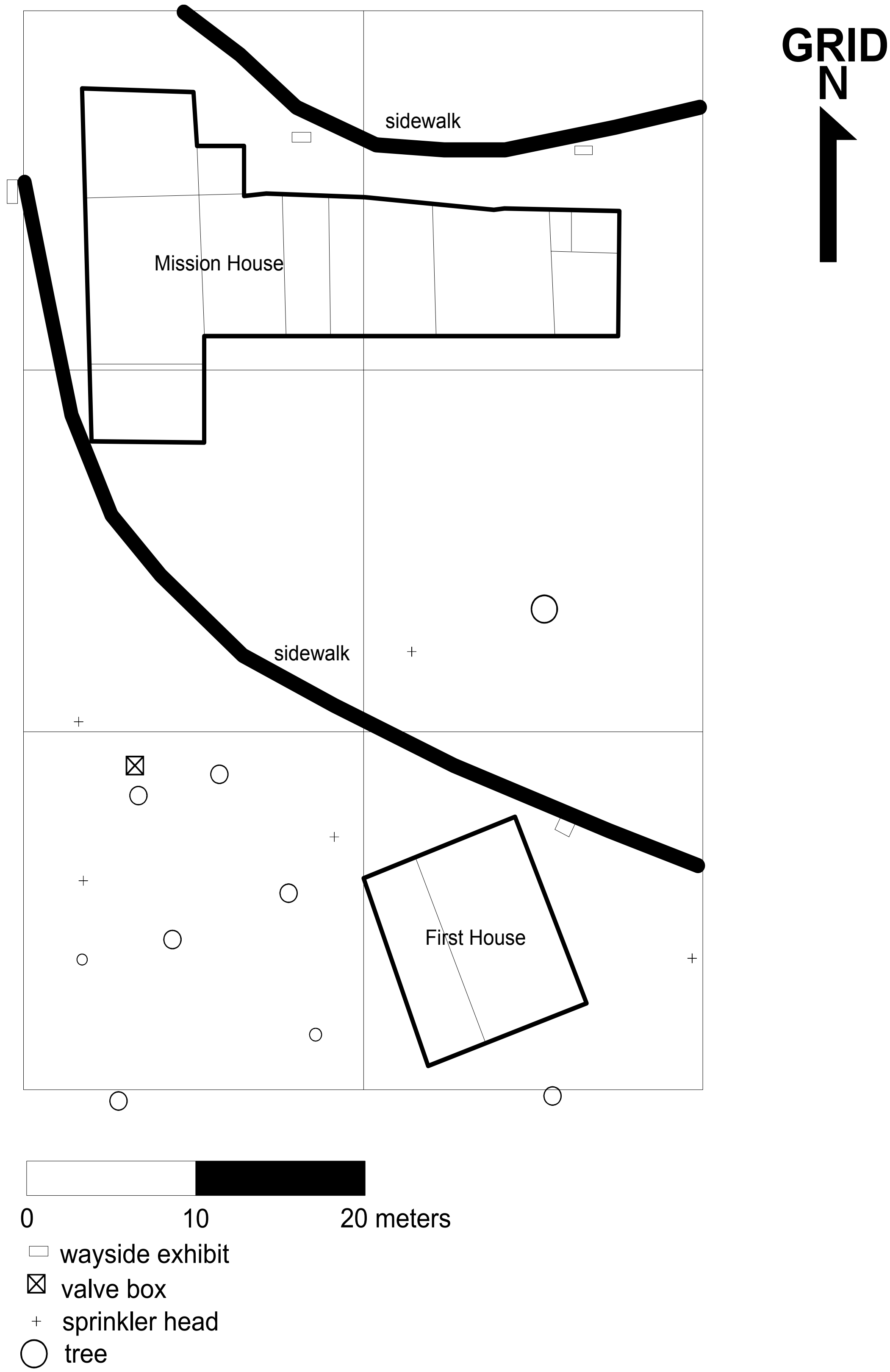


Figure 7. Sketch map of Block 1.

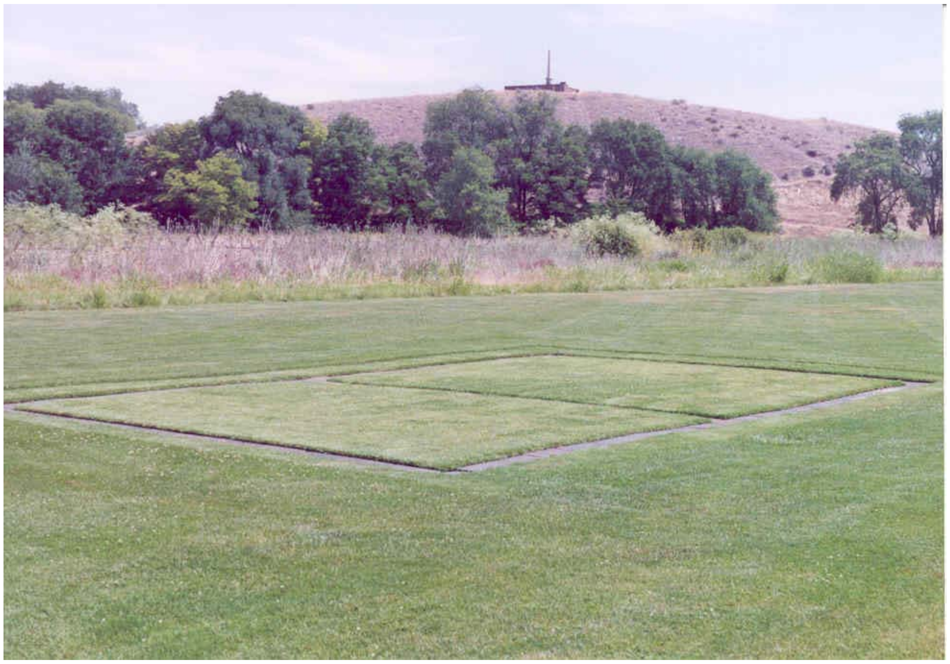


Figure 8. General view of the Blacksmith Shop area (view to the northeast).

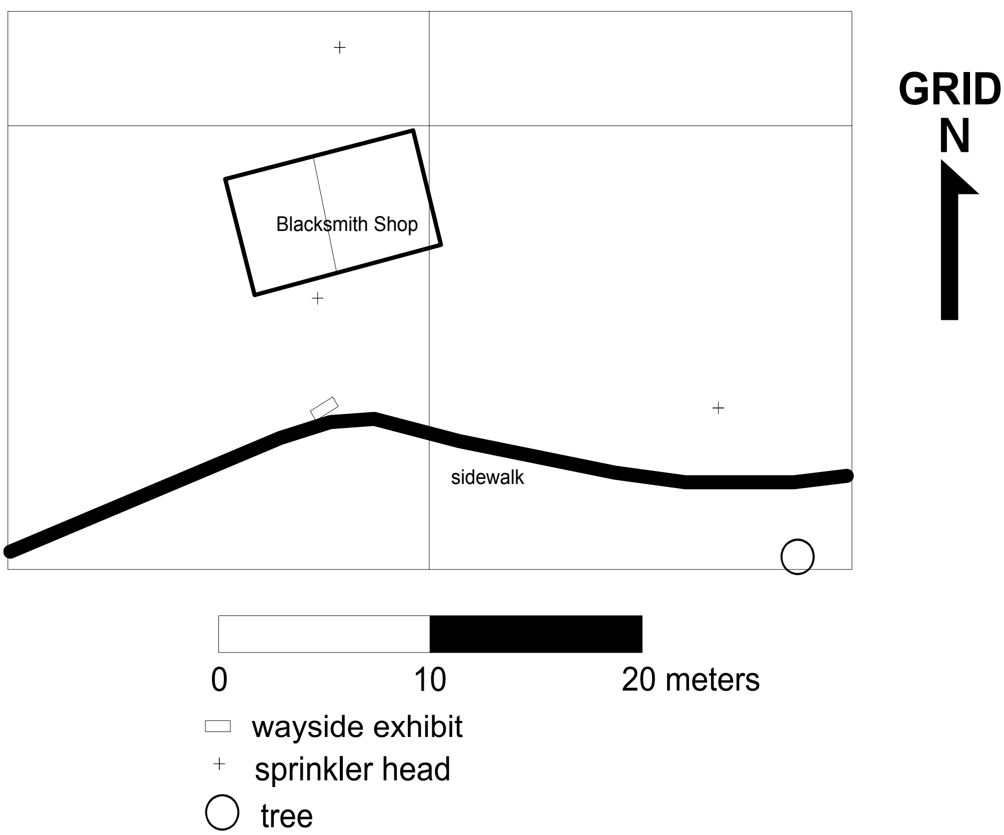


Figure 9. Sketch map of Block 2.

Figure 10. General view of the Emigrant House area (view to the east northeast).

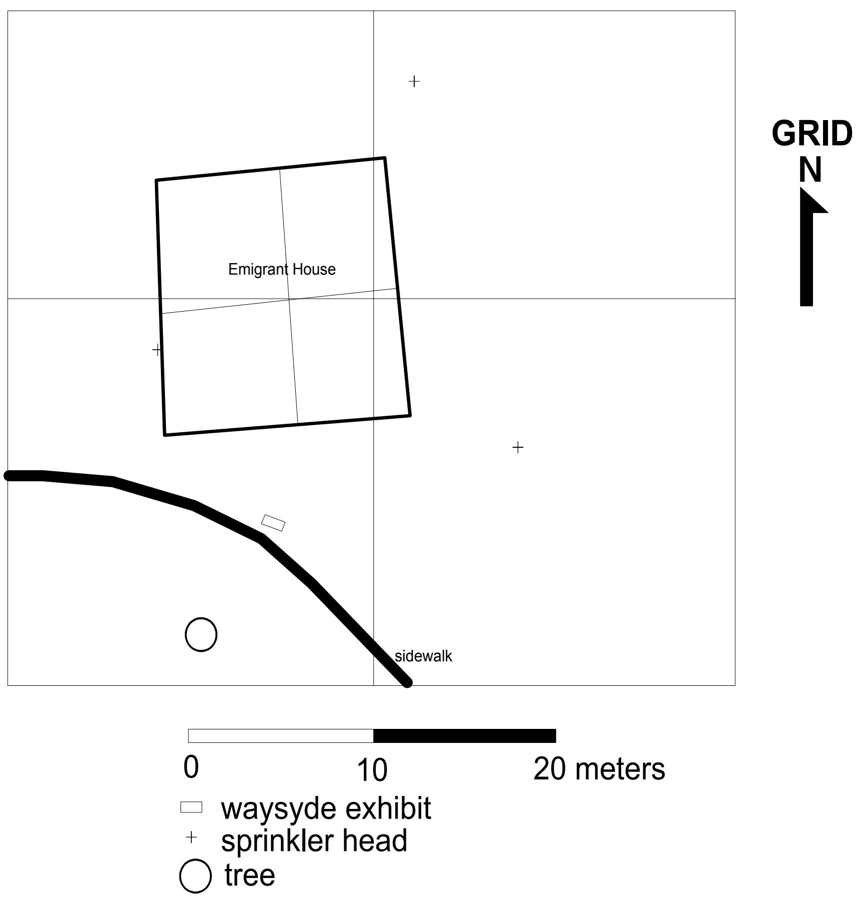


Figure 11. Sketch map of Block 3.

Figure 12. Conducting magnetic gradient survey with fluxgate gradiometer (view to the northwest).

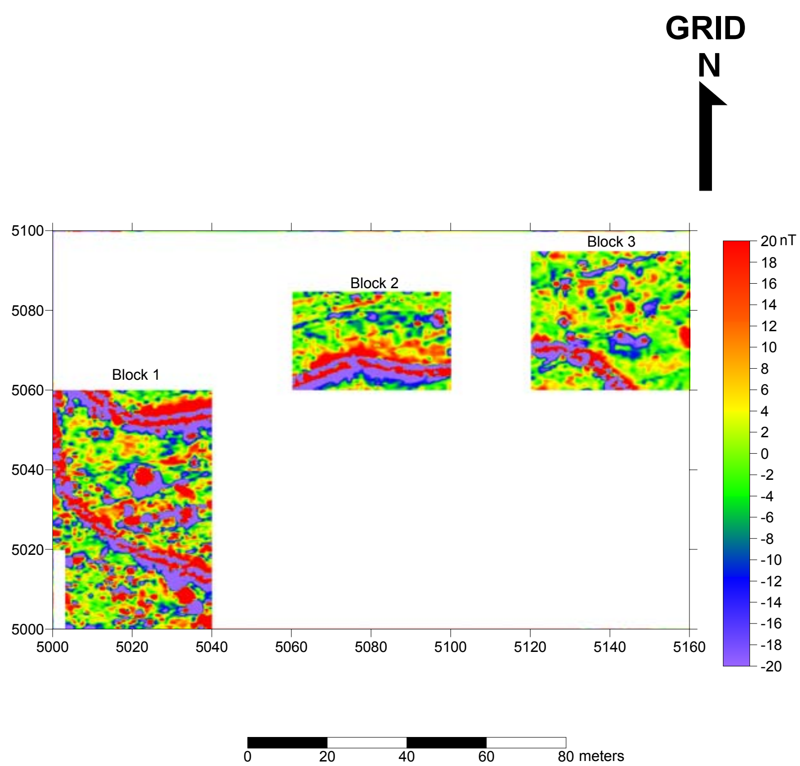


Figure 13. Magnetic gradient data from Whitman Mission National Historic Site.

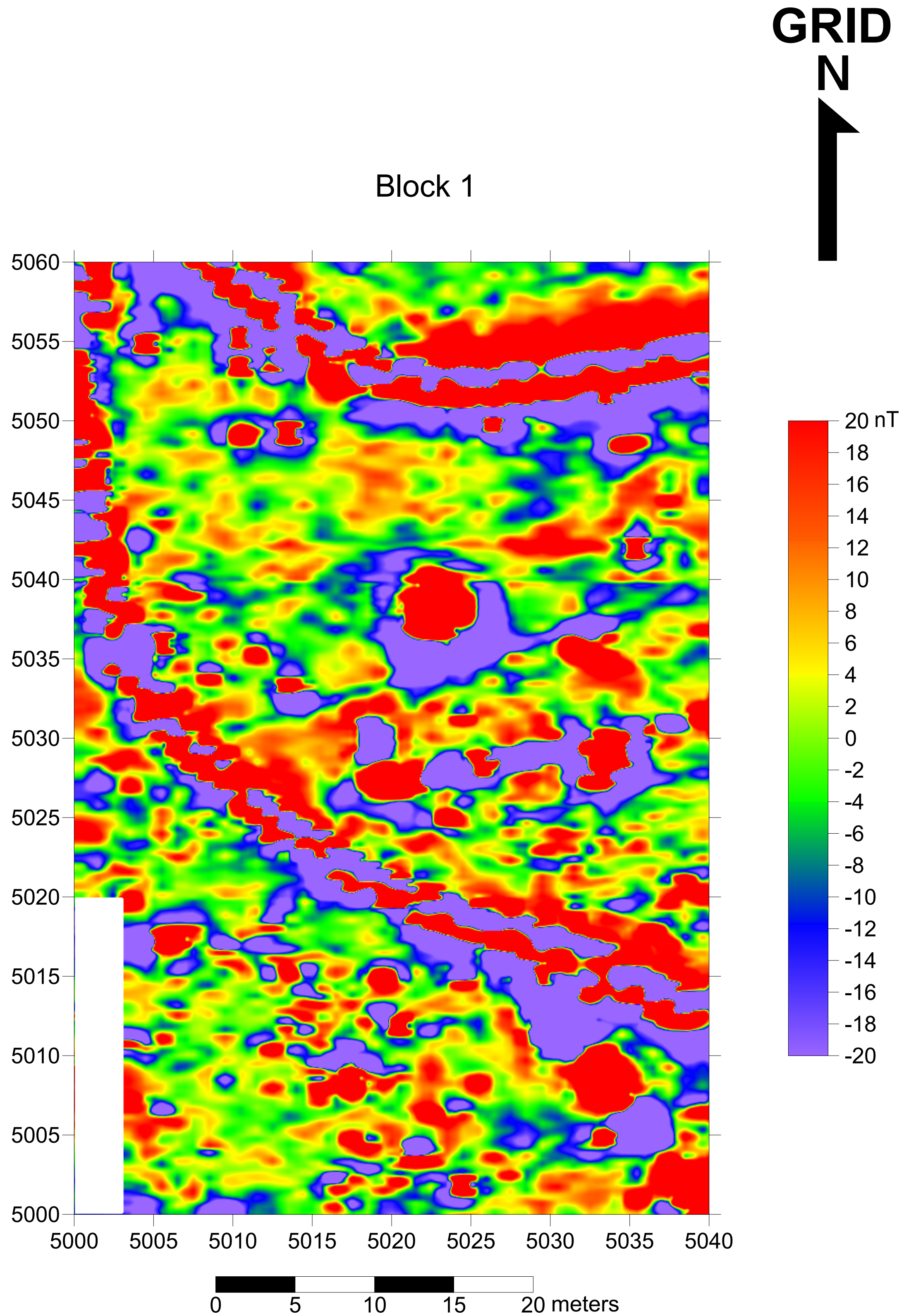


Figure 14. Image plot of the magnetic gradient data from Block 1.

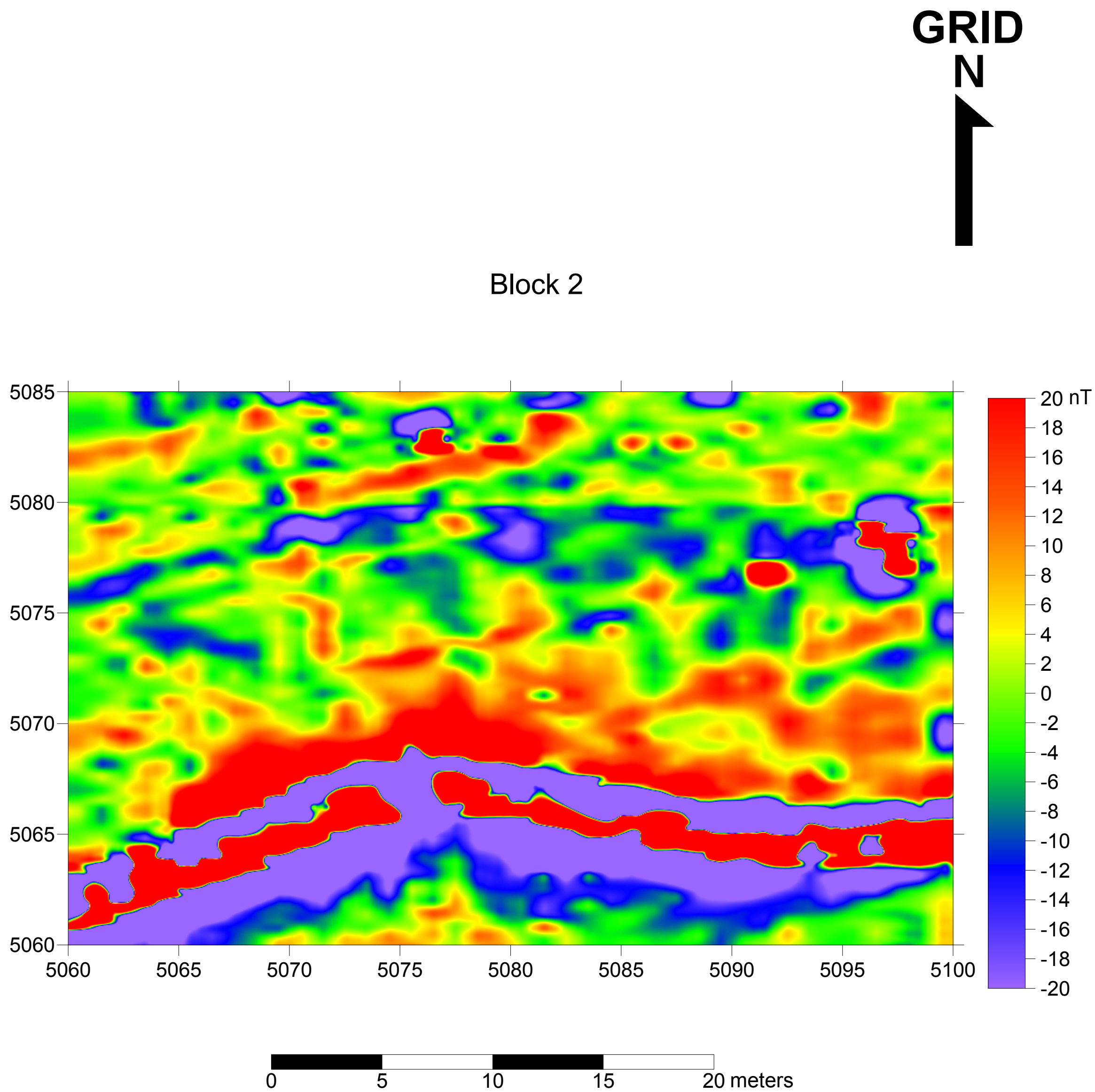


Figure 15. Image plot of the magnetic gradient data from Block 2.

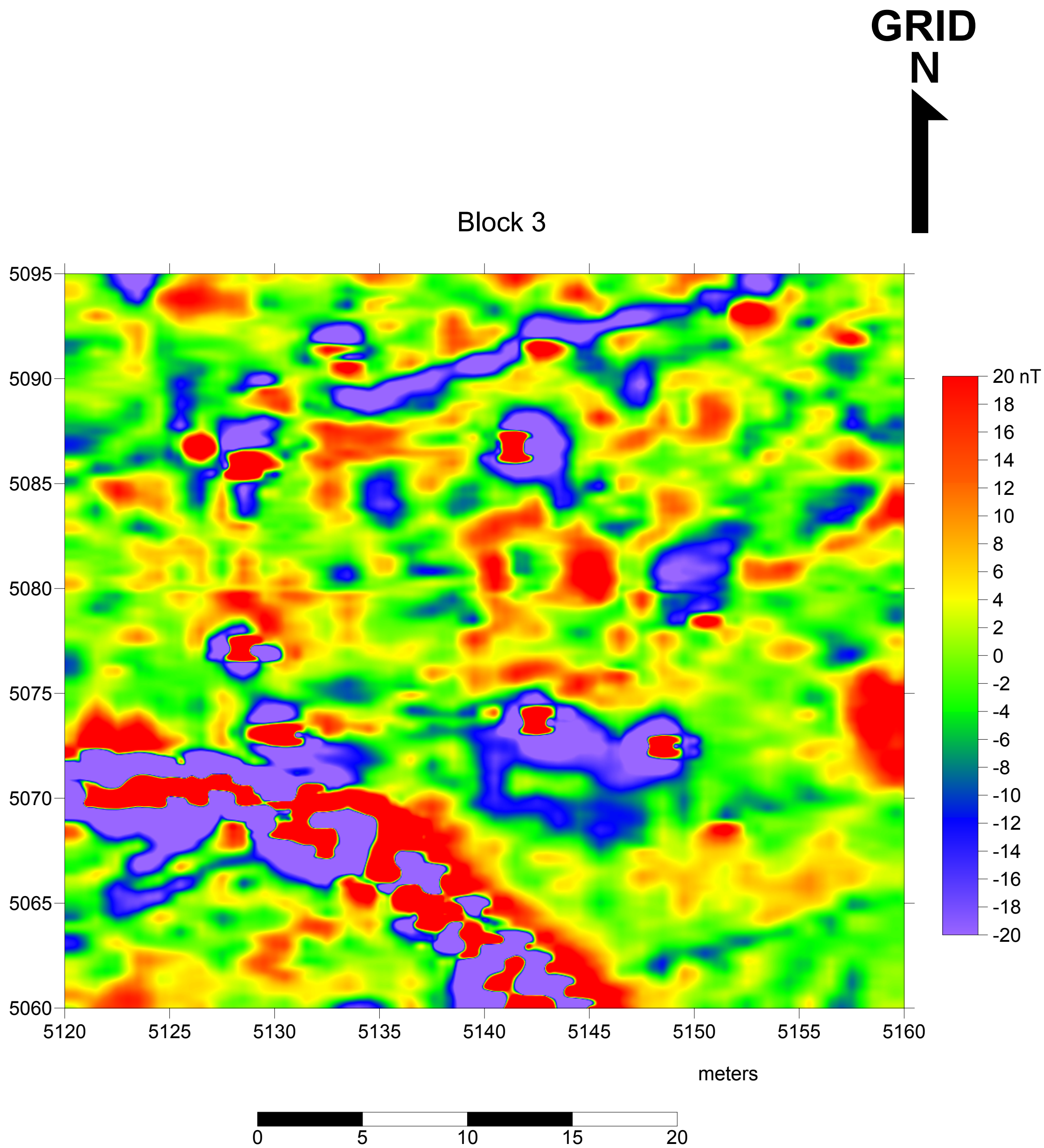


Figure 16. Image plot of the magnetic gradient data from Block 3.

Figure 17. Conducting conductivity survey with EM38 ground conductivity meter (view to the northwest).

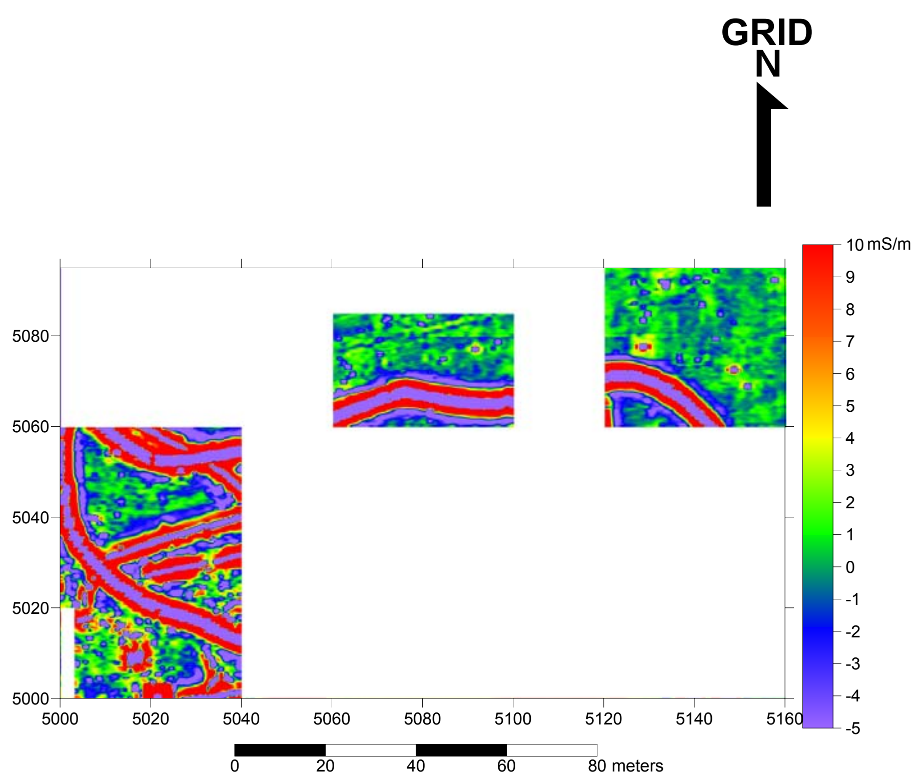


Figure 18. Conductivity data from Whitman Mission National Historic Site.

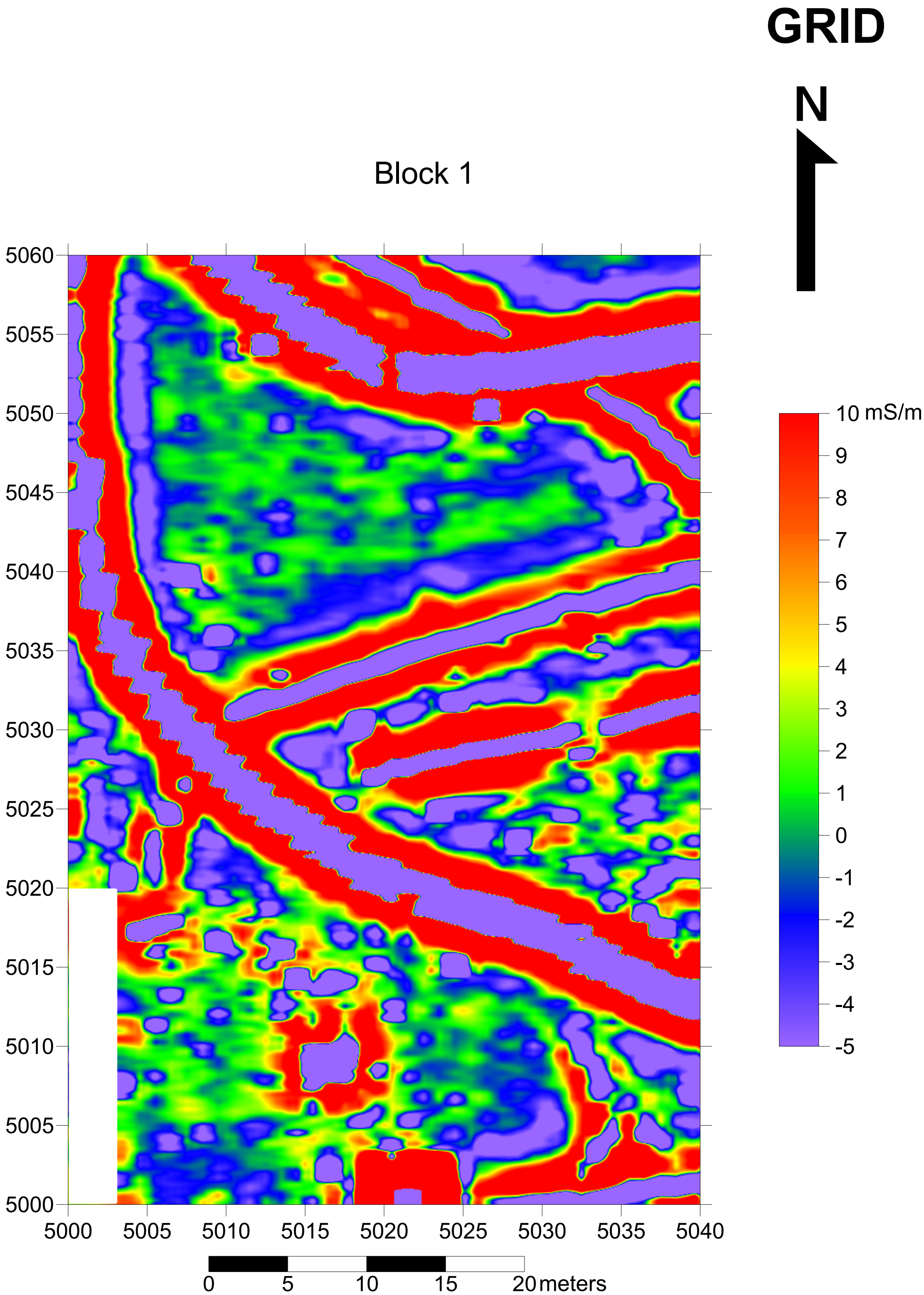


Figure 19. Image plot of the conductivity data from Block 1.

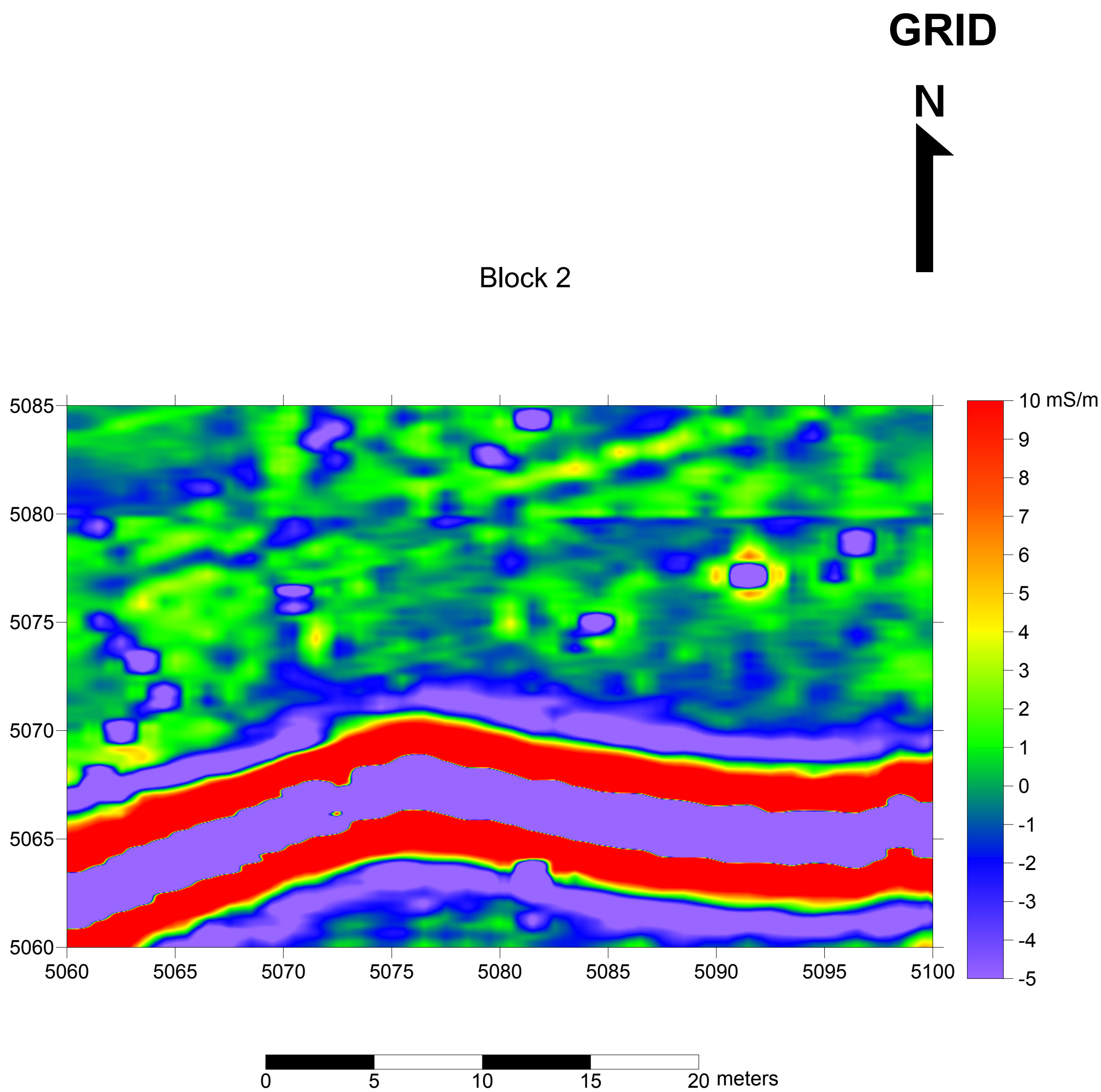


Figure 20. Image plot of the conductivity data from Block 2.

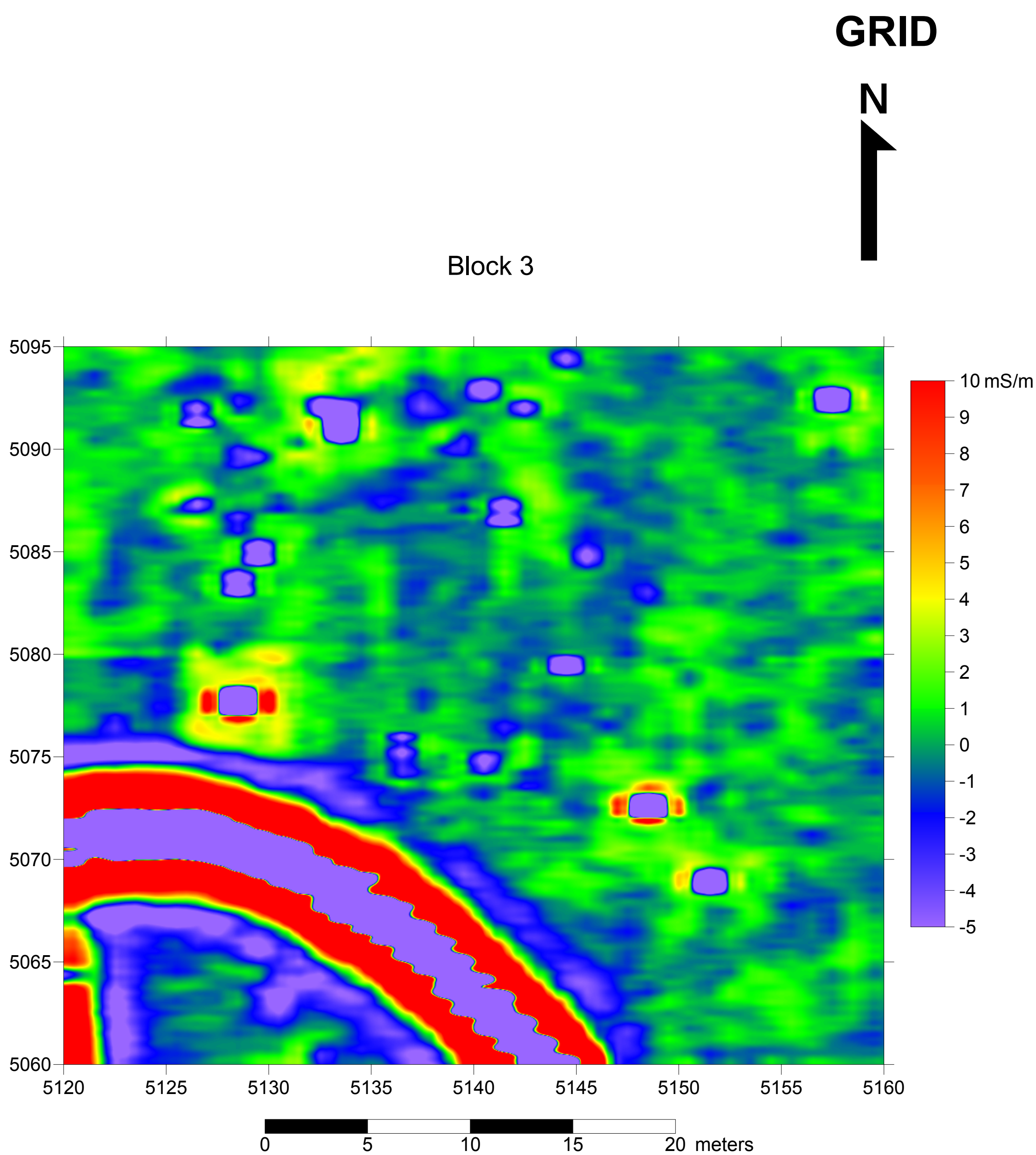


Figure 21. Image plot of the conductivity data from Block 3.

Figure 22. Conducting ground penetrating radar survey with gpr cart system and 400 mHz antenna (view to the west).

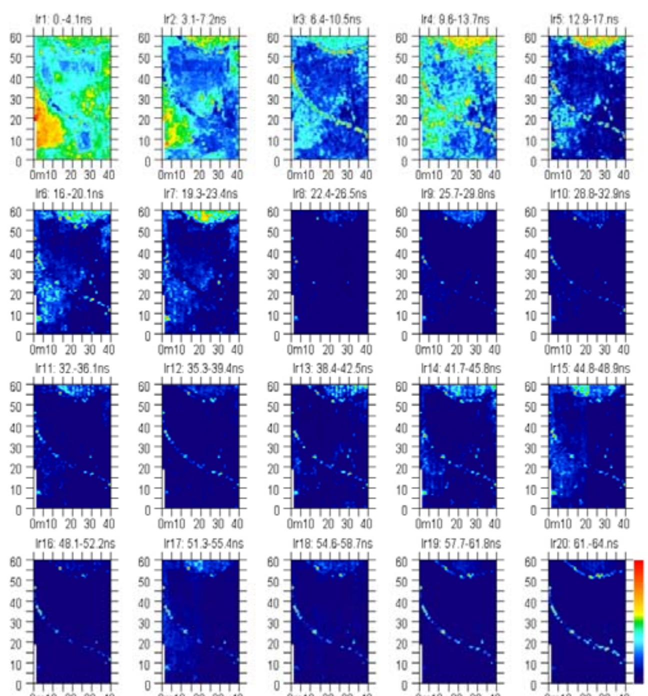


Figure 23. Ground penetrating radar time slice data from Block 1.

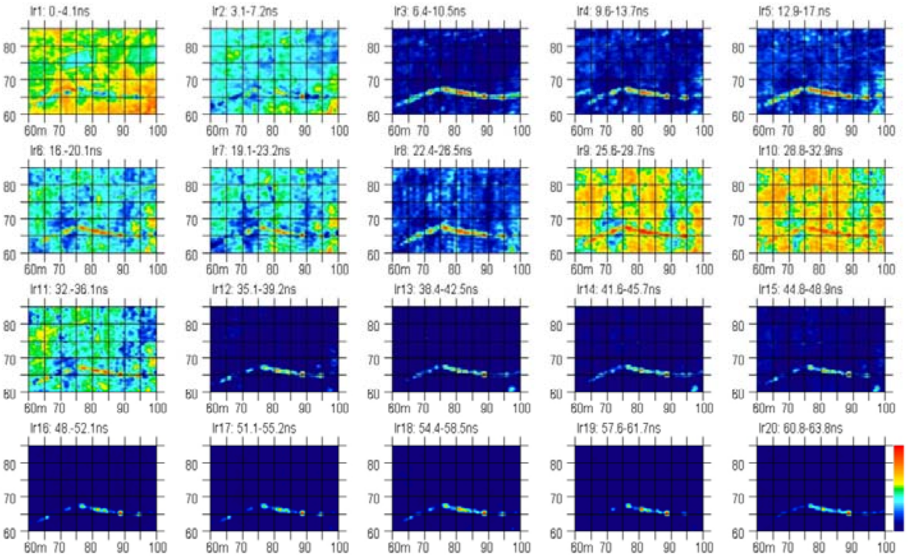


Figure 24. Ground penetrating radar time slice data from Block 2.

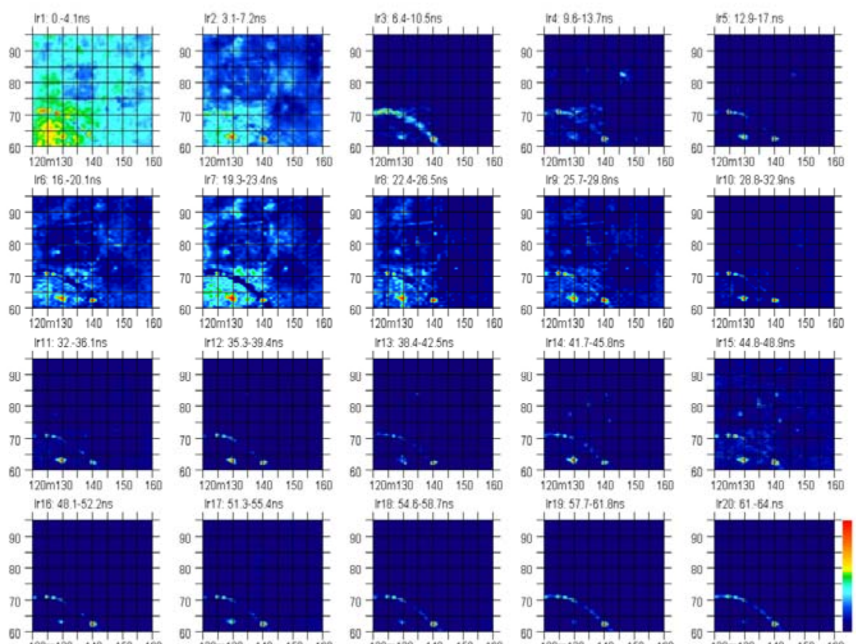


Figure 25. Ground penetrating radar time slice data from Block 3.

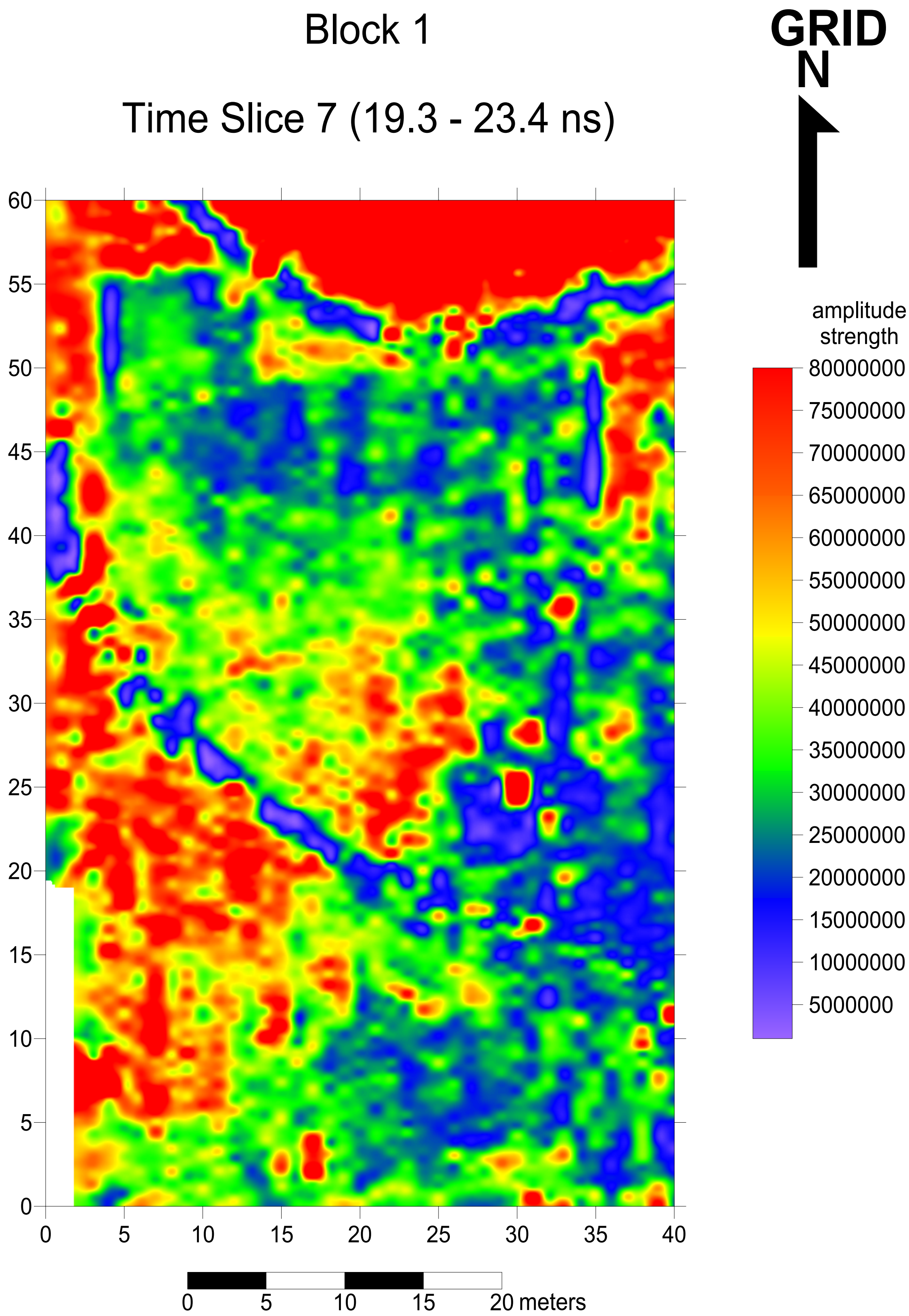


Figure 26. Image plot of the time slice layer 7 gpr data from Block 1.

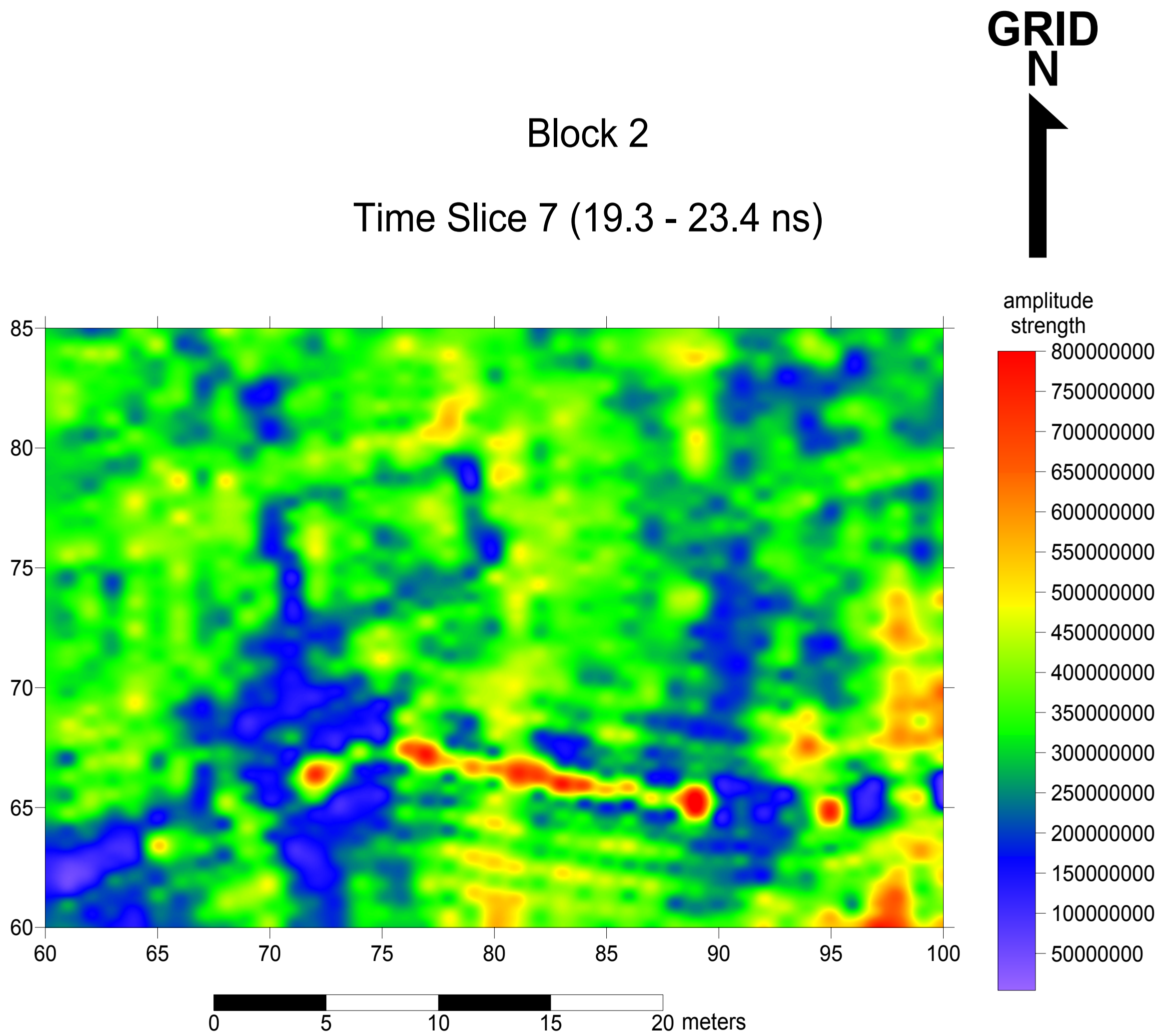


Figure 27. Image plot of the time slice layer 7 gpr data from Block 2.

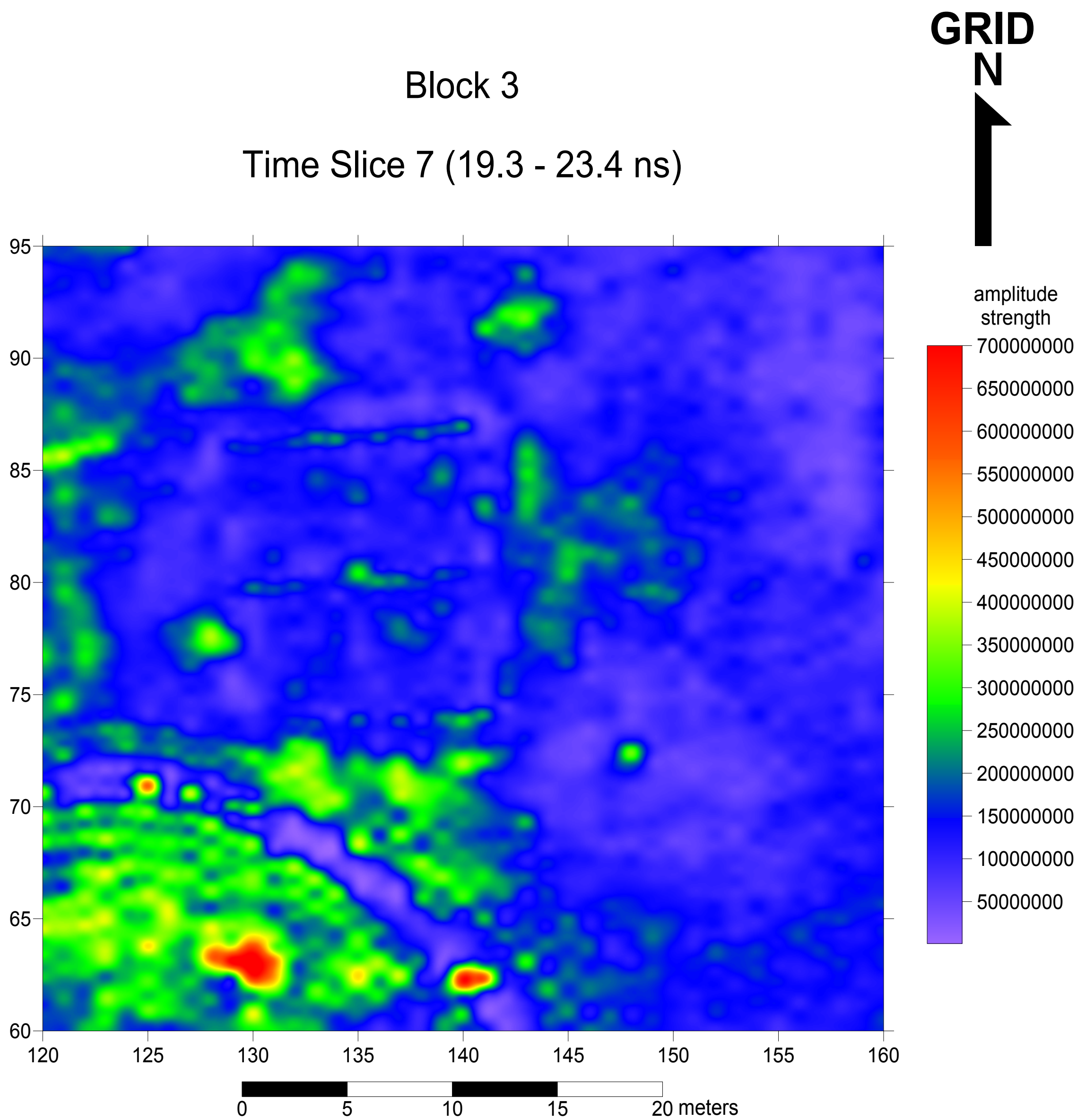


Figure 28. Image plot of the time slice layer 7 gpr data from Block 3.

Figure 29. General view of the pioneer cemetery location (view to the northeast).

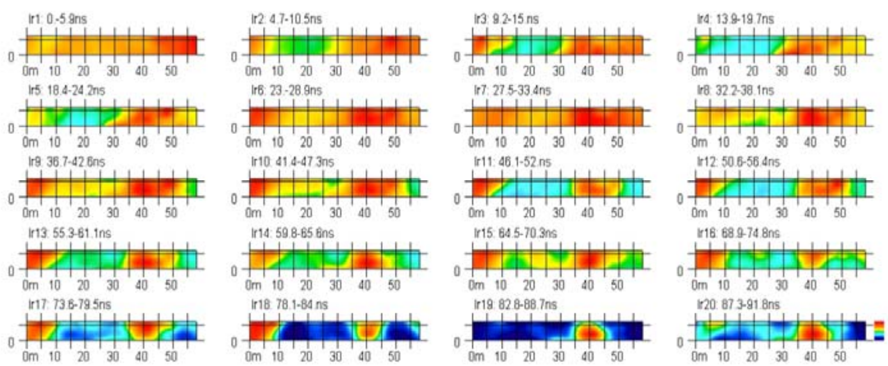


Figure 30. Ground penetrating radar time slice data from the pioneer cemetery.

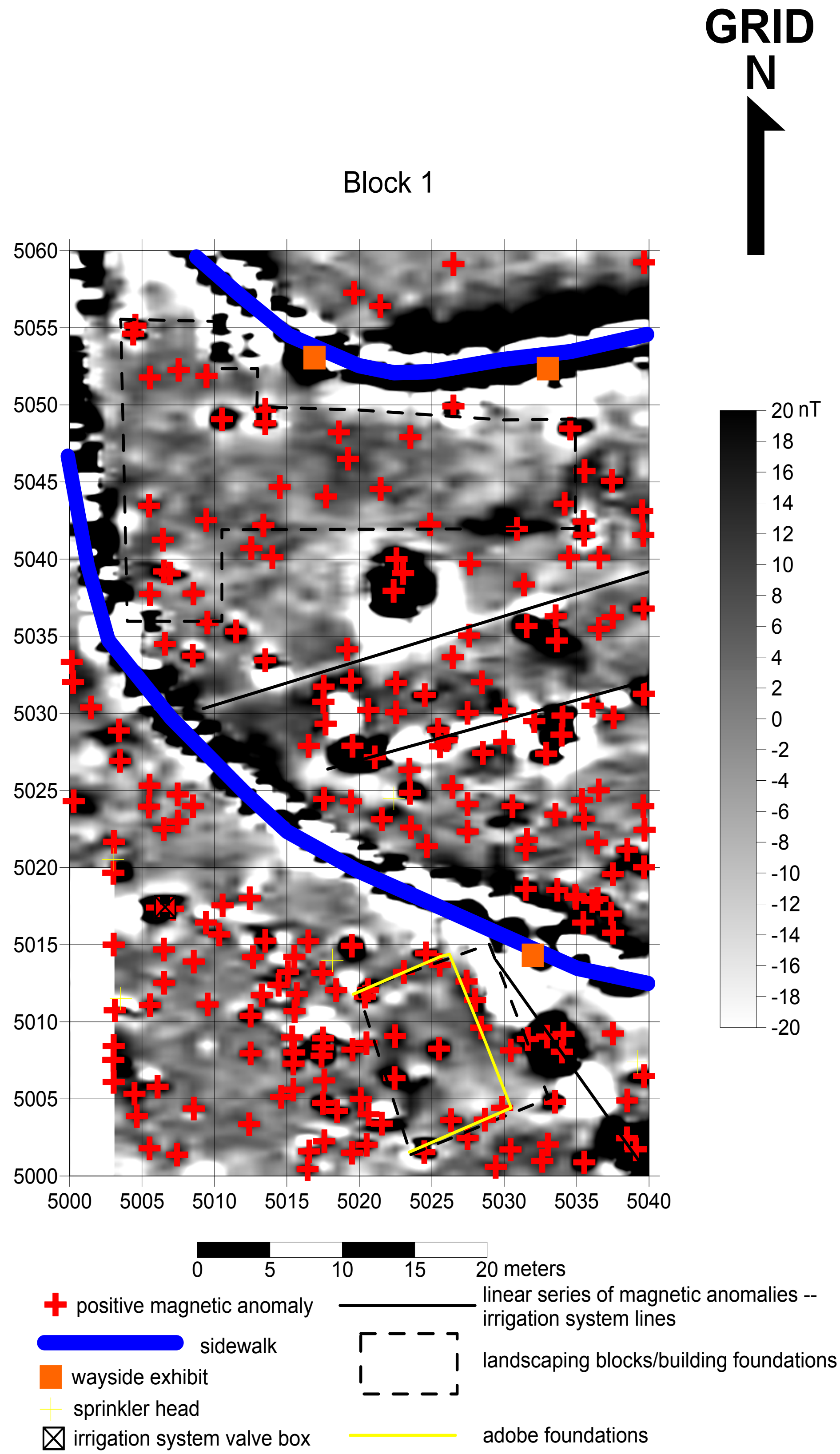


Figure 31. Interpretation of the magnetic gradient data from Block 1.

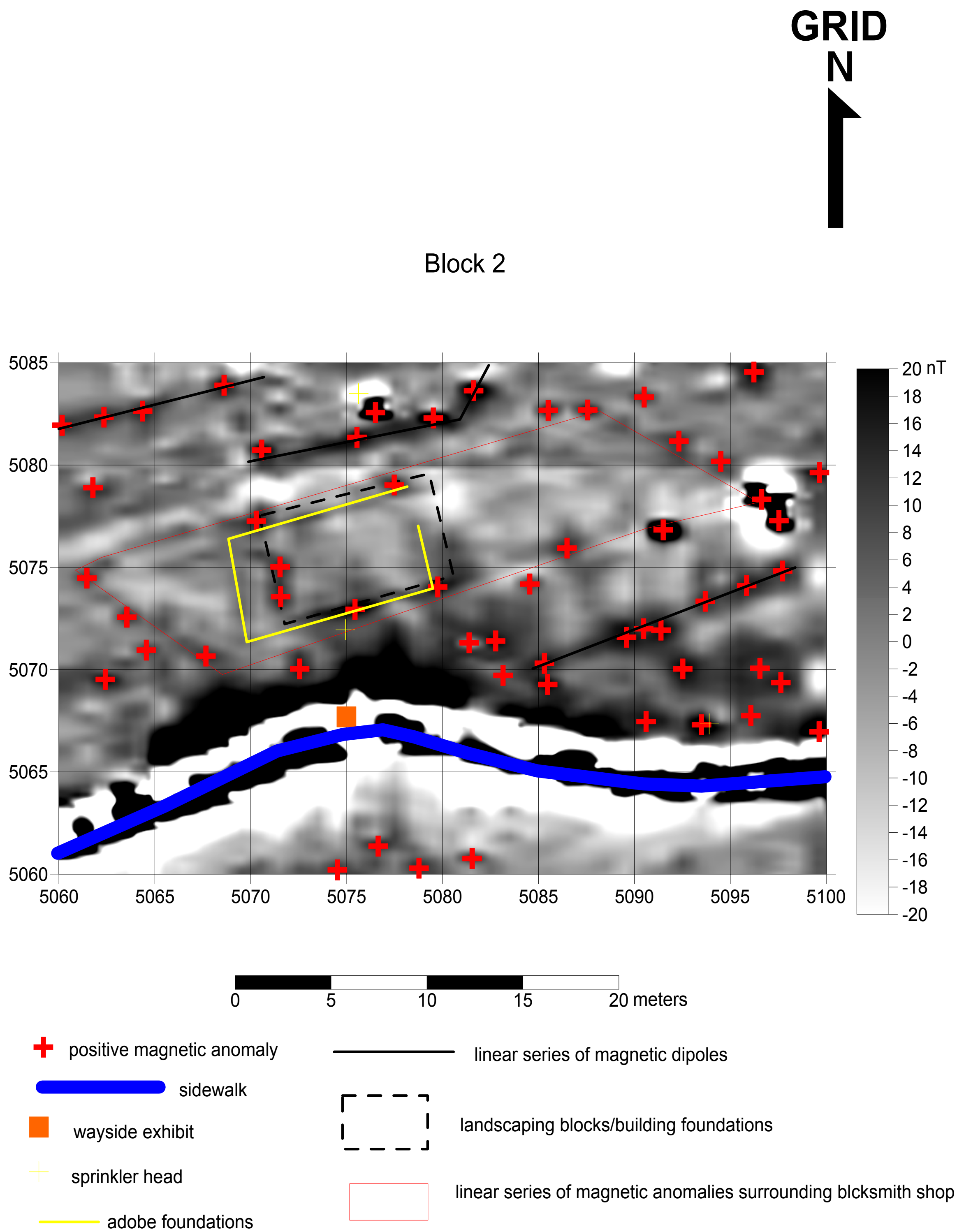


Figure 32. Interpretation of the magnetic gradient data from Block 2.

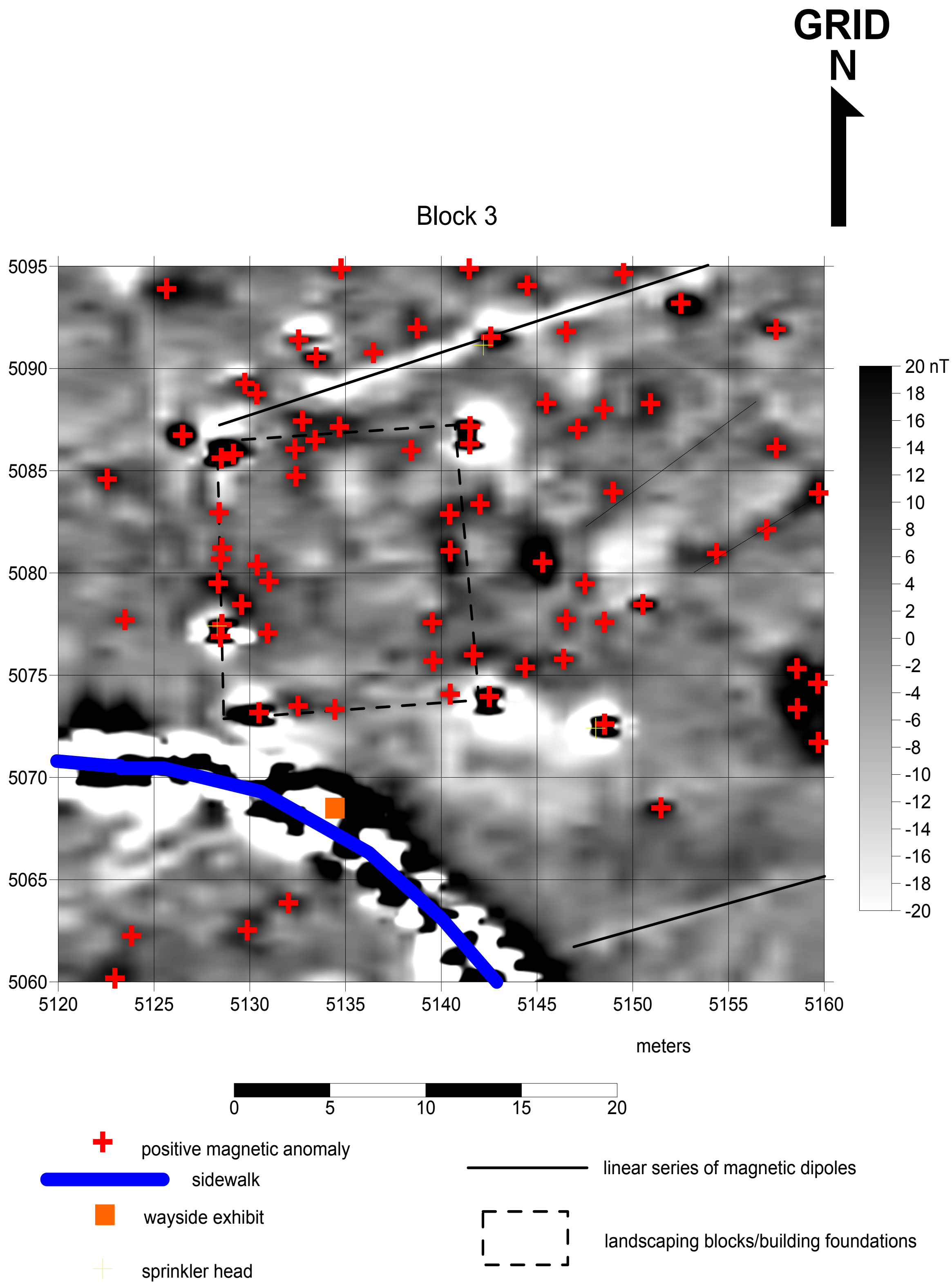


Figure 33. Interpretation of the magnetic gradient data from Block 3.

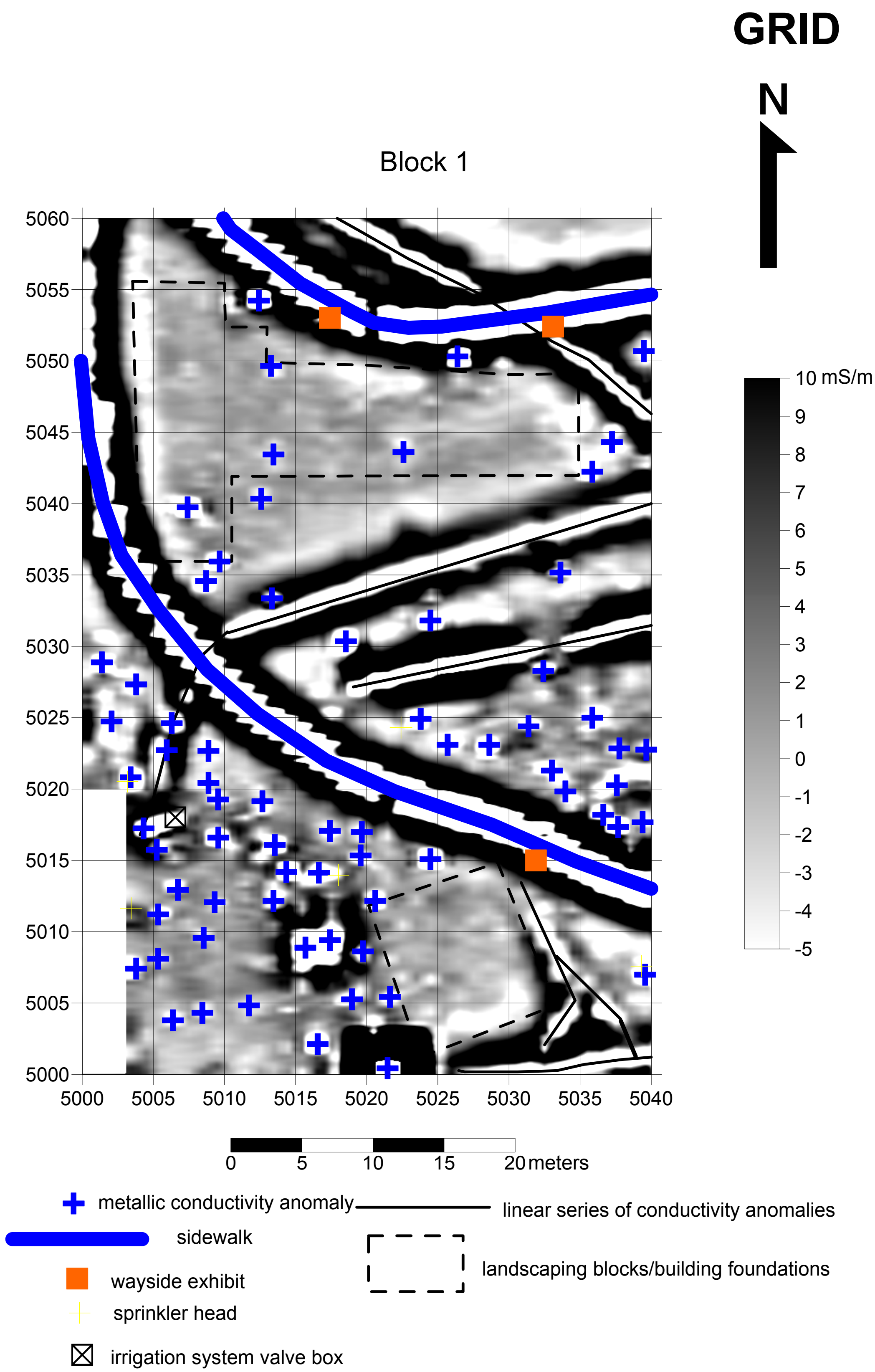


Figure 34. Interpretation of the conductivity data from Block 1.

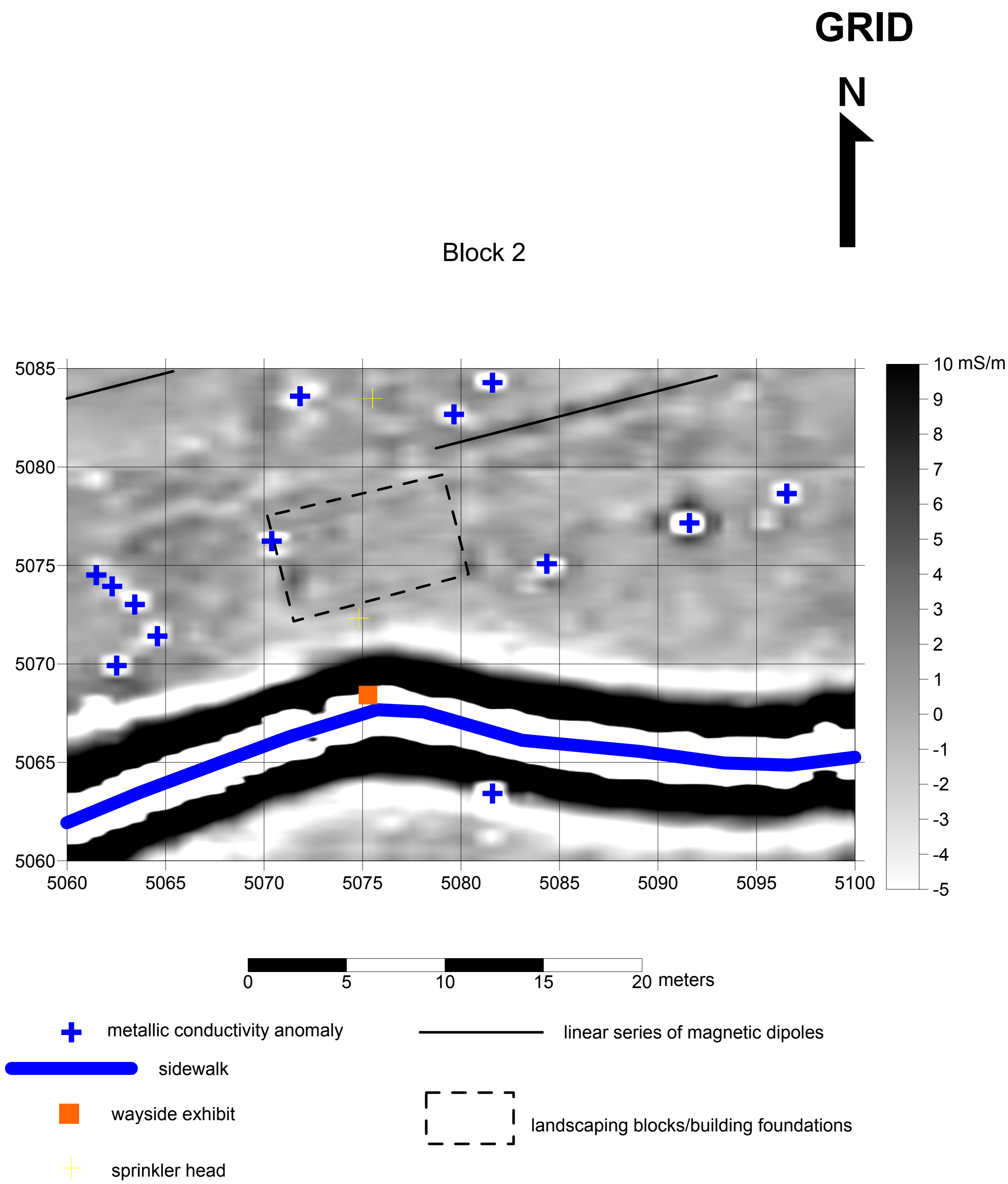


Figure 35. Interpretation of the conductivity data from Block 2.

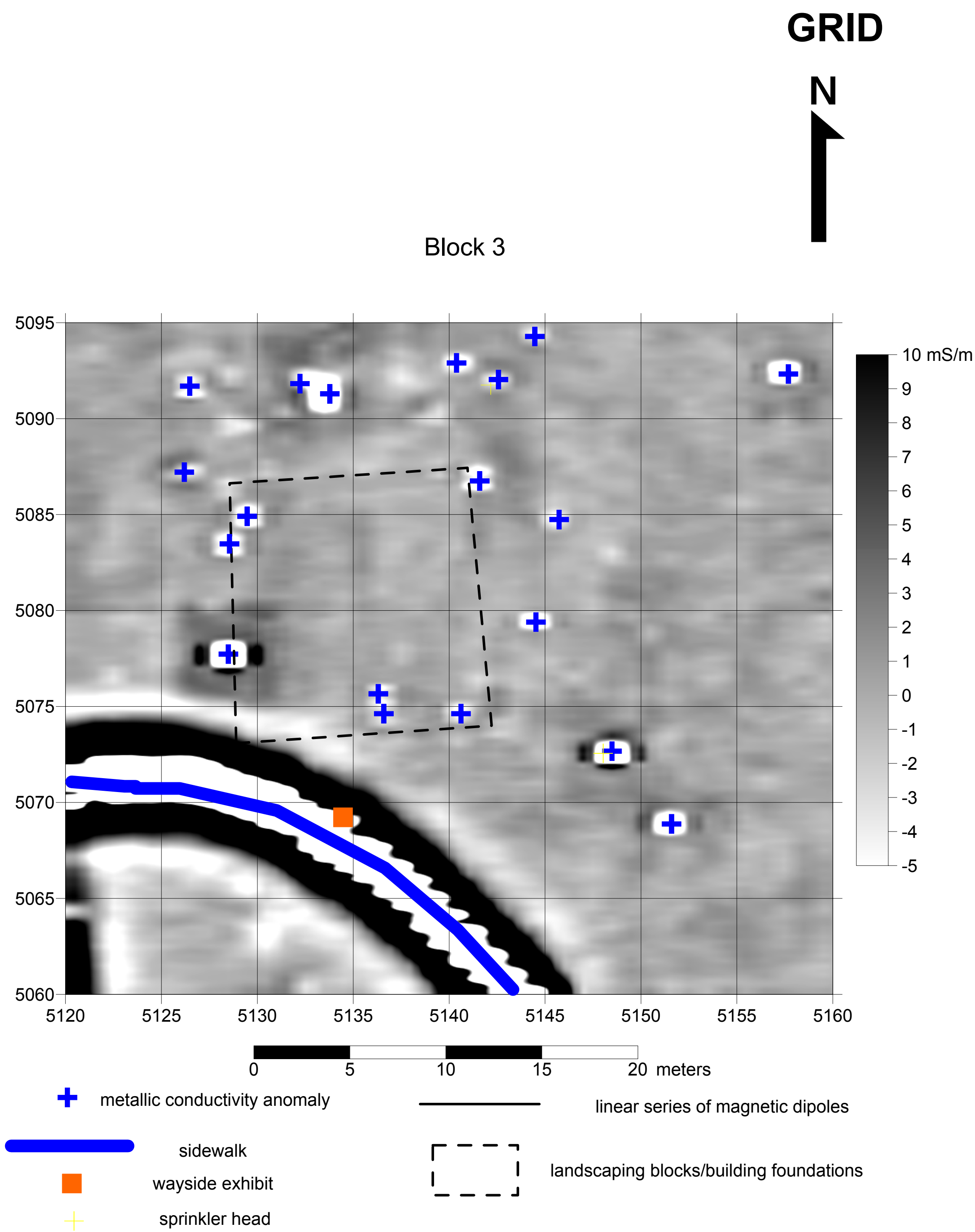


Figure 36. Interpretation of the conductivity data from Block 3.

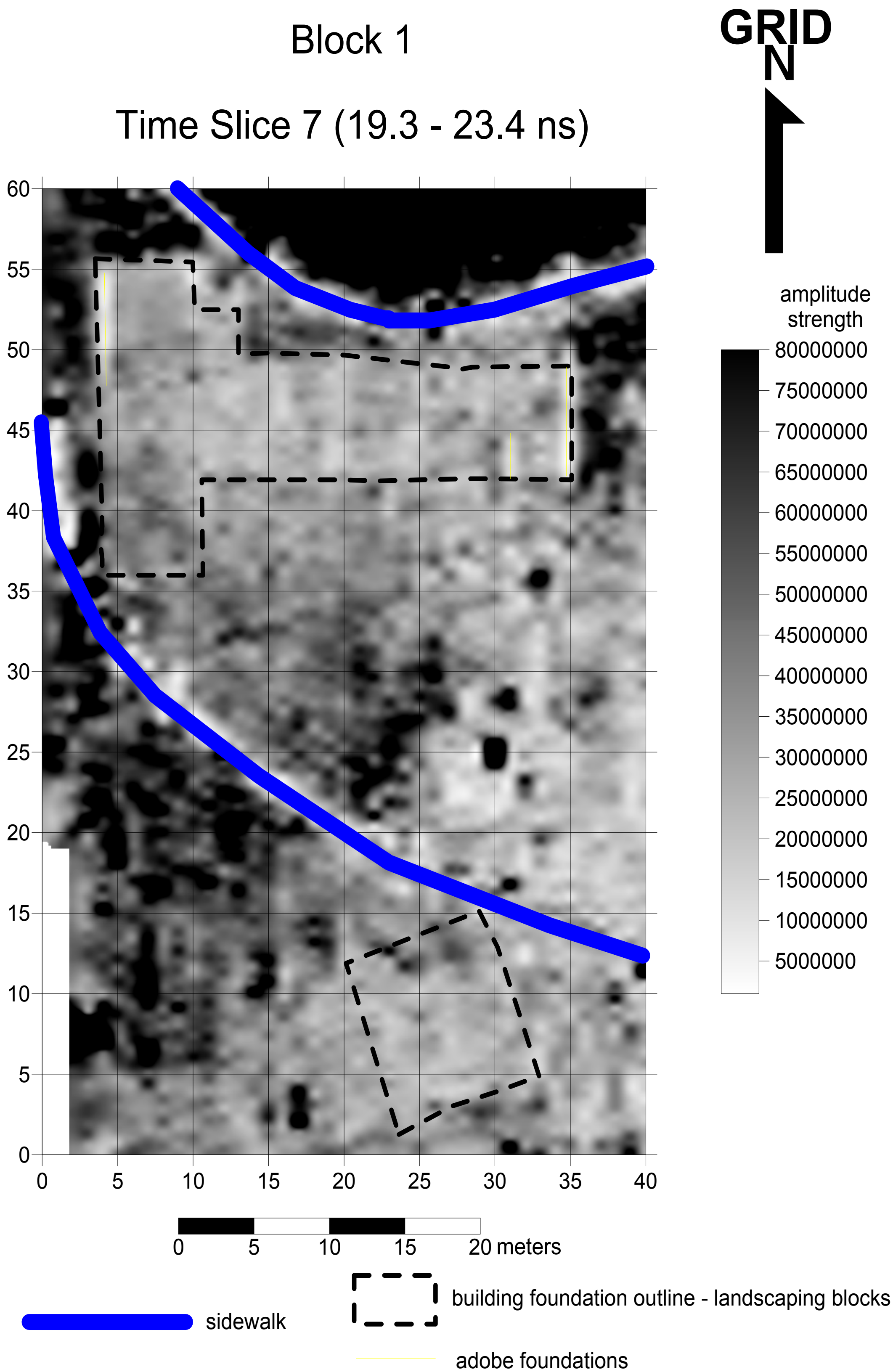


Figure 37. Interpretation of the time slice layer 7 gpr data from Block 1.

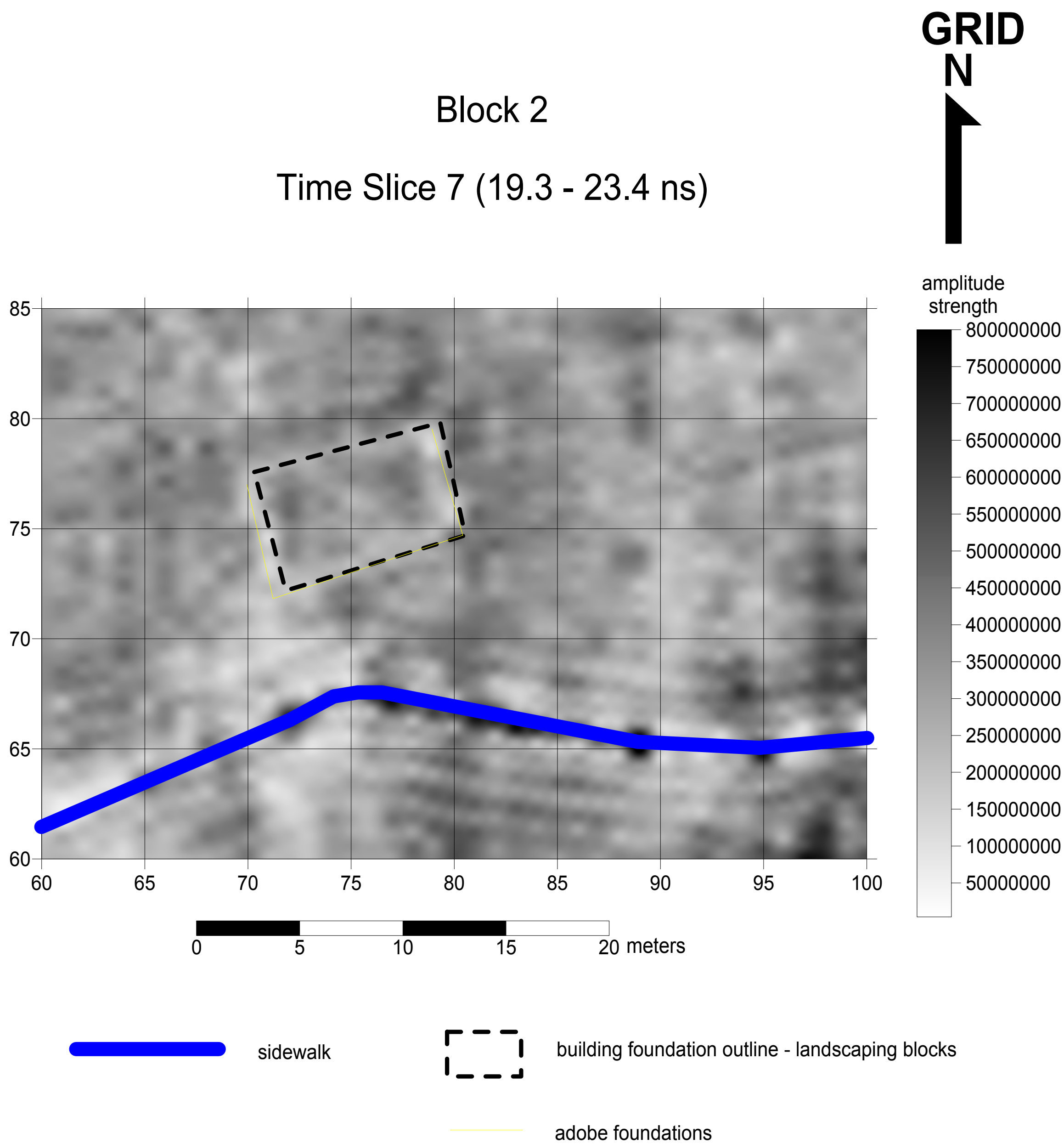


Figure 38. Interpretation of the time slice layer 7 gpr data from Block 2.

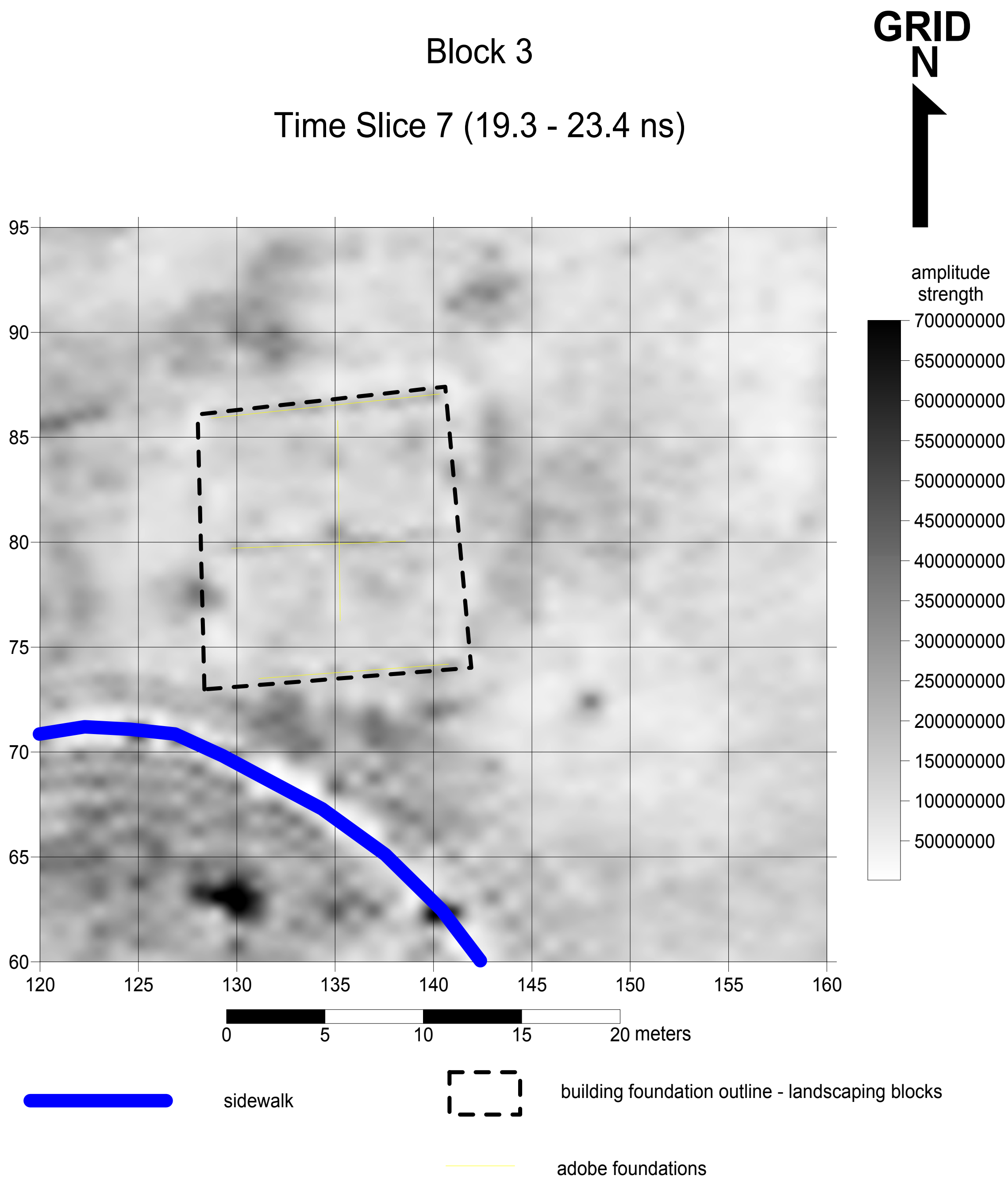


Figure 39. Interpretation of the time slice layer 7 gpr data from Block 3.